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Problem Based Learning in Engineering Education

Dahms, Mona-Lisa

Published in:
Attracting Young People to Engineering

Publication date:
2014

Document Version
Early version, also known as pre-print

[Link to publication from Aalborg University](#)

Citation for published version (APA):
Dahms, M-L. (2014). Problem Based Learning in Engineering Education. In V. VillasBoas, & O. Giovannini (Eds.), *Attracting Young People to Engineering: ALE 2014* (pp. 10-21). Associação Brasileira de Educação em Engenharia (Abenge). <http://www.ale2014.com>

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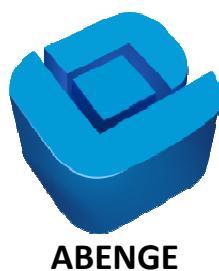
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ATTRACTING YOUNG PEOPLE TO ENGINEERING



EDITORS

Valquíria Villas-Boas
Odilon Giovannini



Brasília
2014

To all our students that, in a daily basis, inspire us.

Dados Internacionais de Catalogação na Publicação (CIP)
Universidade de Caxias do Sul
UCS - BICE - Processamento Técnico

A885 Attracting young people to engineering [recurso eletrônico] / ed. Valquíria Villas-Boas, Odilon Giovannini – Brasília, DF : ABENGE, 2014.
Dados eletrônicos (1 arquivo)

ISBN : 978-85-64541-06-1

Apresenta bibliografia.

Modo de acesso: World Wide Web

1. Engenharia – Estudo e ensino. 2. Ciências – Estudo e ensino. I. Villas-Boas, Valquíria. II. Giovannini, Odilon.

CDU 2.ed.: 62:37.091.3(0.034.1)

Índice para o catálogo sistemático:

- | | |
|---------------------------------|----------------------|
| 1. Engenharia – Estudo e ensino | 62:37.091.3(0.034.1) |
| 2. Ciências – Estudo e ensino | 5:37.091.3(0.034.1) |

Catalogação na fonte elaborada pela bibliotecária
Carolina Meirelles Meroni – CRB 10/ 2187



Lay-out:

Giovani Luis Rech

Sara Andrade de Oliveira

Cover:

Lívia Doncatto Tessari

Publisher:

Editora ABENGE, Associação Brasileira de Educação em Engenharia
SEPN Quadra 516, bloco A, Sala 506 – Ed. Inácio de Lima Ferreira
Asa Norte – Brasília/DF – CEP 70.770-515 - Brazil

Editors:

Valquíria Villas-Boas & Odilon Giovannini

368 páginas

ISBN: 978-85-64541-06-1

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Editorial

Valquíria Villas-Boas & Odilon Giovannini

It has been more and more difficult to motivate high school students to study science and mathematics, in spite of the many efforts made worldwide to show the relevance of these subjects for the formation of engineers. It is necessary to motivate the student to study, to learn how to learn, and various actions can be taken to awaken a taste for sciences and technology in the student. It is the educator's mission to show the relationships between the real world and what is taught in the classroom. High school students need to discover that subjects such as physics, chemistry, biology and mathematics help to describe the world in which they live, to know and to discover existing technologies and to recognize that they serve as a basis for the appearance of future technologies.

Sufficient availability of engineers is essential for a country's economy to have a good competitive position. Knowledge-intensive businesses prefer to operate in an inspiring and innovative climate, and people are no different. That is why we need to attract to engineering as many students as possible, male and female, from all social and cultural backgrounds.

Besides the concern with attracting young people to engineering, there is the concern with the quality of science and engineering education and with the high rates of evasion and failure in the universities. These issues have awakened the interest of an increasing number of faculty members in academic practices inclined towards cognitive development, giving rise to programs and experiments seeking to transform academic practices.

We all agree that students are central to the educational process. As such, they should be active participants in the educational transformation process. In this context, we could ask: "What does it take for the educational experience to motivate students to acquire the knowledge which could be the basis for lifelong learning?"

The student being "active" during the educational process could be the answer and we all know that this is completely necessary but not a sufficient condition. So, where else should we place the emphasis?

Many engineering educators around the world are concerned that the learning environment must move from the lecture as the dominant mode to include a significant level of active learning activities. These approaches should encourage innovative design, development and implementation of processes for engineering programs. They also believe that cooperative learning approaches and other contextual learning experiences must be integrated within the classroom.

Some engineering educators believe that we must encourage faculty to assume a more active role not only in the implementation/delivery of the educational experience for the student, but also in the innovation and continuous improvement necessary for engineering education to meet the challenges.

Definitely, the new requirements for the professional profile of an engineer place demands for new methodologies, differentiated pedagogical approaches and a more consistent vision of the teaching-learning process in order to form a critical and efficient professional that generates knowledge in his/her area. In this situation, active learning and active learning methods, stand out and have been receiving increasing attention from educators in many countries, because they constitute one of the possible responses to the new educational demands of the engineering programs.

For all these reasons, the Centro de Ciências Exatas e Tecnologia of the Universidade de Caxias do Sul (UCS) (<http://www.ucs.br>) is honored to present this book that gathers the contributions presented at the 12th International Workshop on Active Learning in Engineering Education (ALE 2014). ALE 2014 was hosted by UCS from the 20th to the 22nd of January 2014 and was organized by UCS and the ALE network (www.ale-net.org).

The main objective of ALE2014 was to engage engineering educators, researchers in engineering education, curriculum developers, deans of engineering schools and engineering students concerned with improving engineering education through active learning and with using active learning to attract young people to engineering. Attendees of ALE 2014 could participate and engage actively with colleagues from engineering education worldwide to discuss and understand more about how Active Learning can be used to develop and strengthen students' learning and their development of engineering competences. They had the opportunity to gain new insights about learning in engineering education, to develop their teaching practices and met and to extend their network.

The event relied upon dynamic hands-on sessions, debates, poster presentations and interactive keynote lectures. For the keynote lectures, we had the pleasure of receiving Elizabeth Parry from North Carolina State University and Merredith Portsmouth from Tufts University who shared their experiences in attracting young people to science and engineering, as well as Erik De Graaff from Aalborg University and Michael Christie from the University of the Sunshine Coast sharing their enthusiasm on doing research on active learning in engineering education.

We hope this book contributes with new ideas for engineering education and may it help you to find inspiration to attract young people to engineering and to enhance your educational practices.

Valquíria Villas-Boas and Odilon Giovannini

Caxias do Sul, January 2014

HANDS-ON SESSION

Problem Based Learning in Engineering Education

Mona Lisa Dahms

The Faculty of Engineering and Science, Department of Development and Planning, Aalborg University, Aalborg, Denmark

Email: mona@plan.aau.dk

Abstract

Problem based learning (PBL) has gained widespread approval as a student centered and student activating approach to teaching and learning. At Aalborg University this approach has been applied since the foundation of the university in 1974 and the so called Aalborg model has to some extent been developed through 'learning by doing'. In recognition of the long experience with PBL the university was in 2007 granted a UNESCO Chair in Problem Based Learning in Engineering Education (UCPBL) one of the aims of which is to disseminate information about PBL worldwide. The hands-on session at ALE 2014 is aiming towards fulfilling this aim.

Keywords – Educational change; problem based learning; interdisciplinarity; generic competences.

1 Introduction

Problem based learning (PBL) has gained widespread approval as a student centered and student activating approach to teaching and learning. The learning process in a PBL environment takes its point of departure in an ill-structured real-life problem – and this approach has a very strong motivational impact on students' learning processes. One of the recognized strengths of PBL is that, apart from professional engineering competences, students also develop methodological competences in areas such as project management, team work, negotiation, communication, problem solving etc.

The process of change from a traditional learning environment that is teacher centered and teacher controlled to a PBL learning environment that is student centered and (at least partly) student controlled is a process that incorporates a number of elements, such as curriculum development, staff development and institutional development. It is a time consuming and complex process which, if carried out appropriately, can, however, lead to great benefits for all stakeholders in engineering education: students, teachers, institutions, companies and society at large. Therefore, in this paper I will discuss the change process and go into details with some of the elements of change

The first section of the paper is this introductory part. In the second section the change process at large is described and important aspects of the process are discussed. The third section goes into details with the most important element of change, the development of a new curriculum based on PBL. In the fourth section four different models of PBL are described in some detail, while the fifth section discusses the change seen from a teacher's perspective. In the sixth and last section a short conclusion is found, together with recommendations for change to PBL.

2 The Change Process

In this section the process of change from a traditional learning environment to a PBL learning environment will be discussed. Included in the discussion are different aspects of the change process, such as reasons for change, elements of change, strategies for change, factors influencing change and patterns of change.

2.1 Reasons for Change

When discussing educational change it is worthwhile to reflect on reasons for introducing change in engineering education. Reasons that are found in many institutions worldwide are, f.ex.:

- High demand from industry and society in general for engineering graduates with new professional competences in areas such as project management, team work, intercultural communication etc.
- (Too) low employability of engineering graduates due to lack of above mentioned competences and irrelevant curricula being taught in the educational institutions
- Lack of motivation among students, leading to
- High drop-out rates and thus inefficiency in the educational system

While some of the reasons for undertaking an educational change process do vary from institution to institution and from country to country, the growing demand for engineering graduates that are capable of handling the major technological and ecological challenges, taking into consideration the accompanying social and economic challenges, is one major reason for educational change that should be common to all engineering institutions throughout the world.

2.2 Elements of Change

An educational change process should by necessity include at least the following three elements:

- Curriculum development
- Staff development
- Institutional development.

To the above elements may be added a process of 'student development', i.e. preparing students for the change of role of all parties involved in the educational process, including the students themselves. Figure 1 illustrates the different elements of the change process.

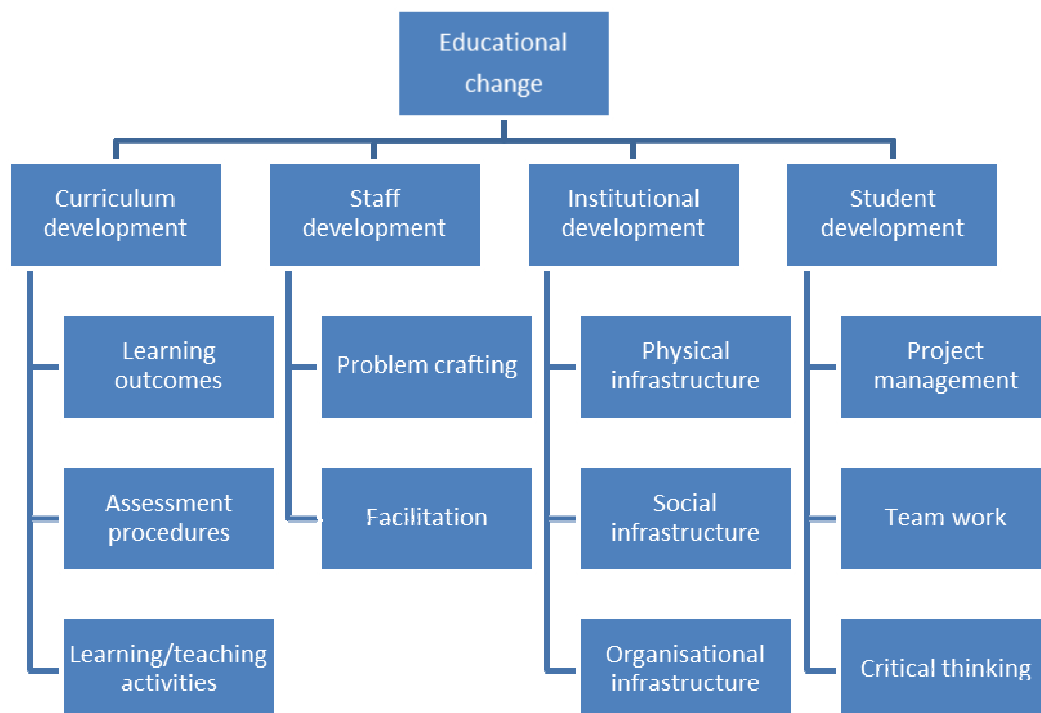


Figure 1: Elements of an educational change process

The curriculum development process consists of developing the new curriculum, including learning outcomes, assessment and learning and teaching activities. The staff development process has as its main focus to prepare teachers, emotionally as well as cognitively, for the changes that take place in their roles as teachers when shifting from a traditional teacher controlled educational approach to an approach that is student centered and (to varying degrees) participant controlled. Included in the institutional development are processes of change in, f.ex. the lay-out and use of physical infrastructure of the institution, the social infrastructure in the form of student support systems and students' access to learning resources etc. Student development may include, among others, training in project management, team work, critical thinking etc.

2.3 Strategies for Change

When observing educational change processes around the world, one can see that in some places the strategy applied is a top-down strategy where management decides to introduce PBL without much involvement of staff in discussions, decision-making and training. In other places a bottom-up strategy is applied where one or a few very committed staff members may decide to introduce PBL within their own teaching, without any support from top management. Neither strategy is recommendable if the change is to be sustainable.

The top-down strategy has the advantage that change is indeed introduced, but with a reluctant and hesitant staff who has received (too) little training in preparation for the change, the chances are that 'resistance to change' takes over

and the actual teaching delivered is not in accordance with what was envisioned by management. The bottom-up strategy has the advantage that a change, true to the spirit of PBL, may indeed be introduced, but because it is very dependent upon few people the change may often fade out and teaching may return to the traditional approach when the committed staff member(s) eventually gives up, either due to change of position or due to fatigue.

The recommendable strategy is a combination of top-down and bottom-up: The top-down managerial support for the change and the existence of committed and dedicated staff members who with the support of management can initiate sustainable change from the bottom-up. The change process may possibly start within one department and then eventually spread to other departments, once the results start proving the value of the change.

2.4 Factors Influencing Change

According to Thousand and Villa (1995) the following 6 factors should be present in order to achieve successful change: Visions; consensus; skills; incentives; resources; action plan.

Within the institution that is aiming to undertake an educational change process, top management are responsible for formulating the **visions** and for creating the **consensus** among staff and managers at all levels, while middle level management may be in charge of formulating an **action plan** together with committed staff members who are keen to be part of the change process.

While awareness raising workshops and seminars about the change process should be arranged for all personal, management and teachers alike, those staff members interested in being directly involved in the teaching of the new curriculum should be more intensively trained in order for them to achieve the **skills** necessary to function effectively in a PBL environment. **Incentives** should be provided to participating staff, whether teachers or management, in a format suitable for the particular institution and department. Of course the **resources** needed to prepare for the change should be in place which is a joint responsibility of top and middle level management.

2.5 Patterns of Change

Very few existing institutions are in a situation where they can 'wipe the board clean' and start planning a complete curriculum from scratch. Therefore, in most cases change has to be a gradual process, starting on a small scale and gradually spreading from course to department to institution. Thus, one way of getting started with the change to PBL is by introducing a short problem oriented project or case as a student activity at the end of an already existing course. If the professional contents of the course is sufficiently broad it may be possible to identify a suitable real-life problem, the solution of which can be worked out by mainly drawing upon the theories and methods from within the one course, i.e. a disciplinary project or case.

A better approach is to draw upon professional contents from two or more courses from within the same or related fields of engineering for the solution of an identified real-life problem, i.e. introduce an interdisciplinary problem. The reason why the interdisciplinary problem is to be preferred over the disciplinary problem is that real-life problems by nature are interdisciplinary – disciplines exist in academia but not in real life.

This interdisciplinary approach does, however, often present a difficulty in many institutions where teachers are used to consider teaching a 'private' activity which is not shared or discussed to any significant degree with colleagues. Thus, for interdisciplinary teaching to occur teachers have to collaborate across disciplinary borders and jointly identify suitable real-life problems drawing upon theories and methods from disciplines involved - and possibly also upon theories and methods from other disciplines that students may have to study on their own.

Given that one of the main reasons for changing to PBL is the motivational impact that PBL has on students, the introduction of real-life interdisciplinary problems should preferably take place at the very beginning of the study and the teaching period. In this way the students' motivation and interest will be aroused from the beginning, (s)he will pay more attention to what is being taught and (s)he will learn better because the purpose of the learning is known: the solving of the problem.

2.6 Summary

In this section the process of educational change from a traditional teacher-centered and teacher-controlled environment to a PBL environment has been discussed. Reasons for change, elements of change, strategies for change, factors influencing change and patterns of change have been discussed. In the ALE 2014 hands-on session one of the topics presented will be educational change and participants will discuss potentials and barriers for change within their own institutions.

In the next section one of the important elements of change: Curriculum development for PBL will be discussed in more detail.

3 Curriculum Development for PBL

In this section the important process of curriculum development, i.e. designing a new PBL curriculum, including formulation of learning outcomes, design of assessment procedures and planning of learning and teaching activities to support students in achieving the learning outcomes, will be described and discussed. The curriculum development model described will automatically lead to achievement of constructive alignment, a principle applied in high quality curriculum development that will also be discussed in this section.

3.1 The Logical Curriculum Development Model

According to Cowan (2003) most often a traditional 'input-oriented' curriculum development process is a chronological process, proceeding from a definition of teaching aims to planning the teaching activities which are then delivered and eventually the assessment of students follows at the end of the teaching. In contrast to this chronological model the curriculum development model presented here is a cyclical and logical model developed by Cowan and Harding (Cowan, 2003).

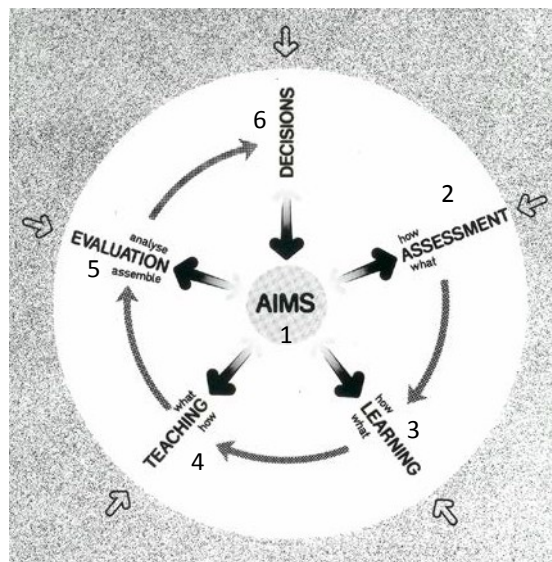


Figure 2: The logical curriculum development model by Cowan and Harding (Cowan, 2003)

According to this model which is shown in Figure 2, curriculum development is a process with six steps:

- 1) The first and most important step is to formulate the aims, i.e. the teaching objectives and the intended learning outcomes, in clear and specific language and communicate these to the students
- 2) Second step is to design the assessment, including the form of assessment as well as the contents
- 3) The third step in the process is to identify students' learning needs, either by anticipating such needs or by responding to students' expressed needs
- 4) Only after having carried through the first three steps comes the fourth step of planning of teaching activities directed towards fulfilling students' learning needs
- 5) The fifth step is evaluation, formative and summative, of the teaching and of students' learning experiences, by collecting data from students, peers, examiners etc.
- 6) The sixth and final step in this cyclical curriculum development process is to make decisions about revision of the curriculum, based on the data collected through the evaluation.

The curriculum development model described above is not specifically related to a PBL setting. It is, however, specific to an outcomes-based or competence-based educational approach, such as PBL, in so far as the (learning) outcomes which are identical to the competences that students are expected to achieve as a result of the teaching process, are in focus throughout the curriculum development process. As such it is a model with focus on student learning rather than on teaching.

In the situation where any one of the intended learning outcomes deals with students' competences to identify, formulate and solve complex and real-life problems, the same curriculum development model should of course be applied and processes of designing assessment, identifying learning needs and designing teaching activities that will enable students to achieve such a learning outcome would be part of the curriculum development process.

3.2 The Principle of Constructive Alignment

Applying the logical curriculum development model by Cowan will automatically lead to fulfilling the important principle of constructive alignment (Biggs, 2003), ie. alignment between learning outcomes, assessment procedures and contents and the actual learning and teaching activities carried out by students and teachers. This important principle which – if adhered to – secures high quality teaching, is illustrated in Figure 3.

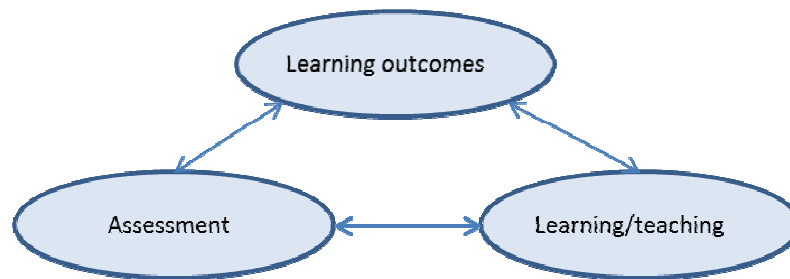


Figure 3: The principle of constructive alignment (after Biggs, 2003)

An interesting discussion in connection with the principle of constructive alignment is to which extent there is a conflict between this principle, according to which intended learning outcomes are formulated by the teacher, and the learning theory of constructivism which states that learning is the individual student's process of constructing knowledge based on information inputs. Another interesting discussion is to which extent there is a potential conflict between the teacher-controlled intended learning outcomes and the procedures in a student centered, participatory learning environment where students have a determining influence on the topic of learning, such as is the case, f.ex., in a problem oriented project or case. Neither of these discussions will, however, be taken up in this paper.

In the ALE 2014 hands-on session one of the topics presented will be curriculum development according to the logical model by Cowan and participants will be discussing the use of the model within their own institutions. Another topic presented will be assessment, more specifically assessment of higher level competences selected by participants among a range of competences.

3.3 Summary

The most important element in a process of educational change to PBL is the development of a new curriculum which is student-centered and focuses on students' learning processes. This curriculum development process should be carried out in accordance with the logical curriculum development model presented in this section. In the process the learning outcomes are at the center of the efforts, securing that the principle of constructive alignment is adhered to.

The next section presents four different PBL models applied in four different institutions throughout the world.

4 PBL Models in Practice

PBL is not a certain prescribed method of teaching and learning. Many universities around the world are practicing one or another model of PBL and no university can claim that their PBL model is the 'right' or the 'best' way of practicing PBL; any educational approach, including PBL, is contextual and depends upon the given university and its context. In this section four different models of PBL will be presented: The PBL model implemented in University of Brasilia; the Republic Polytechnic model with 'one problem per day', the Maastricht model with 'one problem per week' and the Aalborg model with 'one problem per semester'. The models will be described and compared.

4.1 University of Brasilia, Brazil

In Brazil the University of Brasilia may well have been the first university in the world that applied a PBL teaching and learning approach. The university was established in 1960 and started teaching in 1962. The two main aims of the university were: 1) To help solve developmental problems of Brazilian society and 2) to counteract the scientific dependency upon the West. Some of the main characteristics of the university were as follows:

- Problem solving
- Interdisciplinarity
- Experimentation
- Integration of research and teaching
- Critical, incl. self-critical approach to teaching and research
- Collaboration with society

Unfortunately, the university was closed down after the military coup in 1964 and the university population of dedicated and committed teachers and students were killed, jailed, dismissed or fled into exile. Some of the exiled teachers came to Bremen in Germany and here they were assisting in founding a new university that applied PBL. When the two Danish PBL universities (Roskilde University and Aalborg University) were established in 1972, resp. 1974, study tours to Bremen University were part of the preparation and planning.

4.2 University of Maastricht, the Netherlands

In the Netherlands the University of Maastricht (UM) is probably the most famous of the PBL universities. It has been applying PBL since its founding in the early 1970ties. The Maastricht model described below is from the Medical School. Some of the main characteristics of the Maastricht model are:

- Learning based on problems and case studies (= real patient records)
- Integration of disciplines and skills
- Interdisciplinarity secured via interdisciplinary teams of teachers responsible for thematic blocks.

The structure of the curriculum is based on interdisciplinary thematic blocks of 6 weeks duration. Each block contains 6 cases or problems, i.e. one problem per week, with all 6 problems being related to the theme of the block. The students collaborate in tutorial groups of between 8 and 10 students per group. They meet regularly in their tutorial groups, to discuss the problem within the group and with their non-expert tutor who guides the group process, asks facilitating questions, shares his/her knowledge and generally supports the students in the learning process.

One of the well-known elements of the Maastricht model is the so-called seven-step model that describes students' work processes in the tutorial group:

- 1) Clarifying terms and concepts not readily understood
- 2) Defining the problem
- 3) Analysing the problem
- 4) Summarising the various explanations of the problem into a coherent model
- 5) Formulating learning outcomes
- 6) Studying individually
- 7) Reporting and synthesizing the newly acquired information.

Steps 1 – 5 serve as a preparatory phase within the tutorial group for the individual self-study in step 6. After being presented with the problem or case, in steps 1 to 3 the students are expected to elaborate on their prior knowledge in order to come to understand the problem to such an extent that they are able to summarize explanations of the problem in step 4. In the course of this process the students come to realize what they already know and what important information about the problem they still need to acquire and thus they are able to formulate learning outcomes in step 5. These learning outcomes are then guiding the information pursued during the self-study in step 6. The newly acquired insights from the self-study are presented in the next tutorial group meeting, i.e. in step 7, and the seven-step model may be applied a second time around.

A high degree of self-directed learning takes place and skills training and practice oriented sessions are also included in the curriculum. By the end of a thematic block individual examinations are carried out and also individual progress examinations are being held regularly.

4.3 Republic Polytechnic, Singapore

Republic Polytechnic (RP) in Singapore was established in 2002 and was the first institution in Singapore to deliver PBL throughout all its educational diploma programmes. The visions of RP are that their graduates should be:

- Knowledgeable (understand, share, apply)
- Inquirers and thinkers with ability to reason
- Open minded, risk takers and decision makers

- Communicators and negotiators,
- Teamworkers
- Caring and tolerant individuals with a balanced outlook and good values
- Learning-enabled

The RP portfolio includes a total of 7 diploma programmes, each with a duration of 3 years or 6 semesters. Each programme consists of 30 modules. One semester lasts 16 weeks, with 5 modules per semester.

The students in a given programme are divided into classes of 25 students per class, subdivided into 5 teams of 5 students. A facilitator is assigned for the day to each class and a problem is presented by the facilitator in the class in the morning. Since each week contains 5 studying days, this gives a total of 5 different but related problems per week. The schematic for a student's day in RP is shown in figure 4.

Sessions	Activities and actors: f=facilitator, s=students
First meeting (1 hr)	Presents problem trigger + scaffolding (f) Analyse problem (f + s) Identify known – unknown - learning needs (f +s) Assign research duties (s)
First break out (1 hr)	Search, select, structure information (s) Make meaning (s)
Second meeting (1 hr)	Discuss progress and difficulties (s + f) Helps develop learning strategies (f)
Second break out (2 hr)	Review resource materials (2) Peer teach each other (s) Prepare presentations (s)
Final meeting (1 hr)	Present outcomes – discuss, justify, defend (s) Presents 'the sixth outcome' (f)
Assessment (½ hr)	Do an individual written quiz (self assessment, s) Write in personal reflective learning journal (s)

Figure 4: The daily procedure for students in Republic Polytechnic, Singapore.

There are similarities between the RP model and the UM seven-step model, for example, in the identification of known and unknown and the formulation of learning needs and learning outcomes.

In terms of assessment in RP, a written self-assessment quiz is made by each student by the end of each day and a total of 4 'understanding tests' per module and per semester are carried out during the semester.

4.4 Aalborg University, Denmark

Aalborg University (AAU) was established in 1974 and has been applying the problem oriented and project organized team work approach in engineering education since the beginning. The present organization of the study programmes within the Faculty of Engineering and Science is as follows:

One semester lasts 20 weeks, of which 15 weeks are scheduled teaching and studying time while the remaining 5 weeks are time for self-study and preparation for examinations. One semester is credited with 30 ECTS (European Credit Transfer Systems points), with 1 ECTS being approximately equal to 30 hours of study time for an average student, i.e. one semester is equivalent to a total of approximately 900 study hours. Half of this time, i.e. 450 hours is spent on the problem oriented project work that students carry out in groups of between 6 – 7 students in the beginning of the programme and 1 – 3 students by the end of the programme.

The other half of the study time is spent on course work, with three courses of 5 ECTS, each consisting of lectures and related assignments. The courses in a semester are normally designed so as to support the project work, but this is not a requirement. Project work and course work is scheduled so that the majority of course work is concentrated in the beginning of the semester, while at the end of the semester the project work is dominating the weekly schedule. The project is, however, introduced to the students from the very beginning of the semester.

Concerning projects there are several possible ways of formulating projects. In some study programmes the facilitators prepare a project catalogue and students' groups choose one of the proposed projects. Most often facilitators are also open to proposals from students themselves. In other programmes the students are responsible for formulating the projects after a period of initial introduction to the theme of the semester.

In terms of examination there is a group based oral project examination by the end of the semester, based on the written project report that the students have jointly prepared within the group. Examinations in the courses are also carried out, according to different models in different programmes and courses.

4.5 Summary

In this section four different PBL models have been described. In figure 6 an attempt has been made to compare the three existing PBL models, i.e. RP, UM and AAU while the University of Brasilia model has been left out due to lack of information. The models are compared on a range of different parameters. As illustrated in the figure there are remarkable differences between the three models. However, when listening to students from, for example, RP tell about their daily study and about the competences they gain from this study form, the similarities to statements from f.ex. AAU students about their study and their competences, are striking.

	RP	UM	AAU
No. of stud.	5	8 – 10	2 – 7
Lectures - problem work	No lectures (?)	Few lectures	½ lectures ½ project
Length of problem work	One day	One week	One semester
Pre-structure of problem	High	Medium	Low
'Teacher' direction	High	Low	Low to medium
Outcome	Presentation learning	Learning	Report, product, presentation learning
Assessment	Individual Daily+'understand'	Individual Block+progress	Group based Courses + proj.

Figure 6: Comparison of three different PBL models.

The main point is that PBL is not one prescribed way of teaching and learning – each PBL model is unique to the institution and to the context in which the institution is operating. No institution can claim to have developed the ‘right’ or the ‘best’ PBL model – models are simply different and as long as they follow the principles of PBL they may lead to impressive performance of students. In the ALE 2014 hands-on session one of the topics presented will be different PBL models and participants will discuss suitable models of PBL for their own institution.

5 Staff Development

The role of teachers changes rather dramatically once a change from a traditional to a PBL learning environment has taken place. This section will discuss the process of change seen from the teacher’s perspective. Two of the most important tasks of teachers in a PBL environment are crafting of problems that can form the point of departure for the students’ learning processes and facilitation of the students’ learning processes. These two tasks will be described and discussed in this section.

5.1 Change of Teacher’s Role

Seen from a teacher’s perspective one aspect of the change process is a change from a teacher controlled teaching situation based on a behavioristic learning theory to a student centered learning situation based on a social constructivist learning theory that states that learning is the student’s individual process of constructing knowledge by processing information received from different sources of information and in social interaction with others, such as peers, teachers, experts, stakeholders etc. While it may be easy to intellectually state a belief in the constructivist learning theory, it often turns out to be considerably more difficult to act out this belief in the actual teaching situation.

Assuming that all good teachers genuinely care about their students’ learning, the process of letting go of what may be thought to be control of the learning process and handing over this control to the students can by many teachers be perceived as letting go of their professional responsibility in the teaching situation and this loss of control can be mentally demanding and difficult for good teachers. The snag here is that if we truly believe in constructivism we have to realize that as teachers we are never in control of the learning process – only the students themselves can be and are in control here. We have to move away from the psychological mistake about learning:

“We pretend that there is co-incidence between what is being taught and what is being learned” (Illeris, 2006, page 245; own translation).

One way of assisting teachers to take on the role of being a teacher in a PBL environment is to provide adequate skills training and tools to be used in the new environment. Furthermore, based on experience with change processes at Aalborg University, it is recommended to start by directly involving only staff members who are interested in participating in the PBL approach to learning and teaching. In other words, do not try to force any staff members into roles of teaching that they are not confident with and not happy to undertake.

5.2 Problem Crafting for PBL

As mentioned above, two main tasks of teachers in a PBL environment are to craft problems and to facilitate group work. The task of problem crafting will of course depend upon the specific PBL model applied; thus, there is quite some difference between crafting a problem that can be solved within a day and crafting a problem that students will be working with for a semester. In RP, for example, a good part of a teacher’s daily work is to craft problems that are suitable for the ‘one problem per day’ approach applied here, while in AAU problem crafting is a teacher activity that takes place once per semester, and there is a fair degree of re-use of problems, since the students differ from year to year. Another difference between the two institutions is that while in RP the problem is presented to the students together with a so-called scaffolding, i.e. a series of increasingly more open and complex questions that may eventually lead to the solution of the problem, in AAU this work of formulating sub-questions to the overall problem is taken care of by the students themselves. In the ALE 2014 hands-on session one of the topics presented will be problem crafting for PBL and participants will try to craft problems for two different PBL models.

5.3 Facilitation in PBL

Concerning the task of facilitation there are also differences in the functions of the facilitator, depending upon the PBL model applied. The daily tasks of the facilitator in RP can be seen from figure 4. In AAU the tasks of a facilitator vary over the semester, from focus on problem formulation and –analysis in the beginning to focus on the technical solution and the end product in the form of a report and (most often) a technical device later in the project. In order to leave the responsibility for learning with the students, a good facilitator will mainly ask facilitating questions and give

constructive feedback and advise to students' work, but will not attempt to control or direct the flow of work in the project group. Tools that are useful for facilitators in AAU are, for example:

- A contract of cooperation with the students, explicating mutual expectations to the cooperation
- Regular meetings between students' group and facilitator
- Joint formulation of project learning outcomes
- A process analysis at the end of the semester

Armed with such tools the task of being a facilitator in a PBL environment can be eased and chances are that after a short while the teacher will realize the truth of the following quote:

*"Once anyone is involved as PBL-tutor working with students and has the opportunity of seeing what the students can do **when given the permission to think and learn on their own**, he or she usually becomes a convert."* (Barrows, 1996, page 9; emphasis added)

In the ALE 2014 hands-on session one of the topics presented will be facilitation of project work in a PBL environment where participants will perform role plays as students' groups and facilitators, trying out different tools for facilitation.

5.4 Summary

The main point in this section is that for staff to feel confident about a change to a PBL environment and to function well in this environment, adequate training is needed. This training should take place well in advance before the educational change takes place and time should be set aside for staff to discuss and become familiar with their new tasks in the PBL environment. A well-functioning teaching staff is a prerequisite for a successful educational change.

6 Conclusion

The overall topic of this paper was educational change within engineering education. A change to problem based learning may be an expensive and time consuming endeavor but given visionary and supportive management and well well-trained, committed and dedicated staff, the change may lead to results in terms of student competences that are worth the effort.

A summary of recommendations made throughout the paper is given here:

- The strategy for change should be a combination of top-down managerial support and bottom-up initiative from dedicated and committed teachers.
- Interdisciplinary collaboration among teachers should be secured in order to provide interdisciplinary real-life problems for students to work with.
- Real-life problems should be introduced early on in the study programme, when the motivational factor is the greatest.
- The logical curriculum development model presented in the paper should be applied for curriculum development for PBL. Using this model automatically assures that the principle of constructive alignment is satisfied.
- A unique PBL model should be developed, suitable for the institution and for the particular context in which this institution is situated, whether cultural, social, economic or otherwise.
- Teaching staff to be involved in teaching the new PBL curriculum should be provided with ample opportunities for discussions and deliberations leading to mental comfort about the change, as well as ample training leading to cognitive skills in mastering the PBL teaching tasks, such as problem crafting and facilitation.
- Only teaching staff who are interested in participating in the delivery of the PBL curriculum should be involved in the first phases of the change – forcing staff to take on teaching tasks that they are not comfortable with does not lead to sustainable change.

Any questions or comments to this paper are very welcome at: mona@plan.aau.dk.

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Solids of revolution

Isolda Gianni de Lima, Laurete Zanol Sauer

Centro de Ciências Exatas e Tecnologia, Universidade de Caxias do Sul, Caxias do Sul, RS, Brazil

Email: iglima@ucs.br, lzsauer@ucs.br

Abstract

This paper presents a report and a review of the Geometry Workshop: solids of revolution, which joined the Engineer of the Future Project (EngFut Project), developed at Universidade de Caxias do Sul. The Workshop was applied to secondary school teachers and subsequently to their students. The activities have been planned with the purpose of promoting meaningful learning through an active methodology, with fun and interactive challenges, which can lead to new ways of thinking mathematically. More than transmitting content, we promoted the involvement of participants in practical activities that challenged them to estimate, experience, represent, analyze and conclude by encouraging learning through the construction of notions, ideas or concepts. Thus, learning is active and meaningful because it involves the action of the learner to understand meanings.

Keywords: active learning strategy; meaningful learning; do and understand; geometric solids of revolution.

1 Introduction

One goal of EngFut project, developed at Universidade de Caxias do Sul, from 2008 to 2012, was promoting the interaction of the engineering sciences with teachers from different areas, and high school students. Relating the themes of technological areas with social, economic and environmental aspects we sought to highlight the importance of these areas and awake young people's interest in scientific and technological knowledge, which is a relevant objective currently in several countries that realized to be able to implement their technological potential with investments in education and strengthening science education in Engineering and Technology, in general, from the basic levels of education.

In Brazil, the concern with this awakening is present in incentive shares provided by programs, with encouragement from government agencies, which provide innovations in learning and teaching.

However, betting on change requires first cooperation with the continuing education of teachers as the main action to promote improvements in the quality of teaching. Create environments conducive to teachers and their students, dealing with problems, case studies, challenges and interventions in real situations. Creating new opportunities and significant learning through joint actions seems to be a quality alternative to improve relations in education.

In this context of reality, seeking innovative strategies of educational activities, the workshops challenged and stimulated high school students and their teachers to experience learning situations in ways of making Engineering. In this area of training, the daily demands of experiments in laboratories, production of artifacts in interdisciplinary workshops, theoretical reasoning, communication in other languages, the use of technology, interaction with the modes of producing and using knowledge in university in business and technical training schools. This way, everyone will benefit. The teacher improves knowledge of the area where it operates and enhances their pedagogical and student, by this living, awakening to the "World of Engineering" and expanding their talents for future scientific and technological careers.

The act of learning is individual and internal to each subject in the construction of knowledge. Some people learn more autonomously while others are dependent on someone to teach, need external support and encouragement to be motivated to study. However, when there is curiosity, interest or learning strategies everything seems simpler. Considering this fact, many teachers of all levels of education, seek to build and develop differentiated pedagogical proposals, trying to involve students by updating themselves regarding their practices and encouraging them to create and experience more dynamic strategies.

2 Activities performed in the workshop

By organizing the workshop activities, we pursue to draw a didactic and pedagogic framework that could be applied to teachers from different areas and also to high schools students who participated in the project. To make potentially significant activities for all pedagogical strategies were designed to promote the involvement and actions of participants. This involvement is not reduced to solving by models or to solve a set of problems with the application of formulas presented by the teacher, followed by examples of how it can be applied. As regards Ausubel (2003), this involvement entails learning significantly with comprehension of meanings, which requires activating prior knowledge, sharing thoughts on conjecture, recognition and analysis of properties and regularities. According to Piaget (1978) while conducting activities and reflections afforded by good questions, it is possible to direct the ideas for the alleged purpose of learning.

A workshop as a learning strategy, suggests a dynamic operation mode. However, the teacher, interested in describing learning process, should plan each activity with the care that is not only the handling of some materials. According to Becker (1995, p. 21), "[...] students only learn something, which means to build some new knowledge, if they act and discuss their action." So to write material activities, we seek to focus the action, thought and expression of ideas, both orally and in writing. Each workshop participant is a learner, so it must assume the role of subject of the process. The student must act mobilizing prior knowledge, to consider new ways of thinking and resolving situations in dialogue with their peers and with the teacher. The teacher acts as advisor and questioning, enabling this effective action of the student.

For the theme of the workshop we looked for a subject of Mathematics in Engineering, which had a relationship with the nature of engineering and math high school. On the other hand, we had the intention of addressing content in which engineering students experienced difficulties. In disciplines such as the Differential and Integral Calculus, many students suffered losses of several orders because of difficulties in identifying or applying algebraic, geometric or numeric processing at level of basic mathematics.

Given these considerations, the choice of the subject fell on Geometry, which appears frequently in the study of Calculus and that, is, by its nature, the "building science".

As a didactic structure that contemplated the development of active and meaningful learning activities, we opted for a reverse of what usually happens in schools processes. It is quite common in the study of Geometry, even in the spatial geometry, offer to students everyday objects with different spatial forms to be visually explored for the study of areas and volumes. In this workshop, on the contrary, the idea was to promote "mental" construction of solids of revolution and, consequently, the perception of its properties and generalities.

Another component, considered in the planning, was the entertaining quality of the challenges the proposition, the buildings and the interactions between the components of the groups. It expresses a relaxed way of building materials, using them and talking about the observations and conclusions that are made. Not a less successful way, but a strategy with which students are free to act and to express themselves, feeling the urge to question and to address the cognitive imbalances that can lead to new ways of imagining space objects and their representations in plane.

In the workshop activities, which are presented below, we favor own acts of "doing math" as intuition, experience, representation and conclusion. Thus we seek to encourage the development of understanding and capacity to represent ideas and thoughts that take shape as cognitive structures.

- a) Activity for a first interaction between all participants and at the same time to meet the preconditions that would be developed.

Participants were divided into two groups and we asked them to form two lines, one facing the other. Each one received a card that should be kept secret for the components of the other row. For one of the rows, each card contained a picture of a flat region that generates a solid of revolution, and for another, the cards contained the corresponding solids of revolution. Initially, one of the rows showed their cards, with the generating planar regions. The other row still maintained their cards in secret and sought to identify who had the region that would correspond to the solid drawn on their card. Then they did the opposite. The cards with the flat regions were hidden again, and the other line showed the solids of revolution to each colleague to find the solid corresponding to their region. Thereafter, the components of the rows should be directed to partner the other row so that the pairs formed, with the generating region and the corresponding solid of revolution generated.

This first activity, even though it looked simple, showed difficulties of many participants, teachers and high school students. To complement the formation of peers, all interacting, walking around the room, comparing the figures,

discussing and seeking their pair, a fellow with the companion figure, until all pairs were recognized with the flat region and corresponding solid of revolution generating. They ended together forming pairs.

This activity was organized on the basis of Figure 1, a question of proof of the National High School Exam - Enem/1999. Enem is applied annually, throughout Brazil, to evaluate the quality of secondary education and currently is adopted by many Brazilian universities as evidence of selection of candidates for Higher Education.

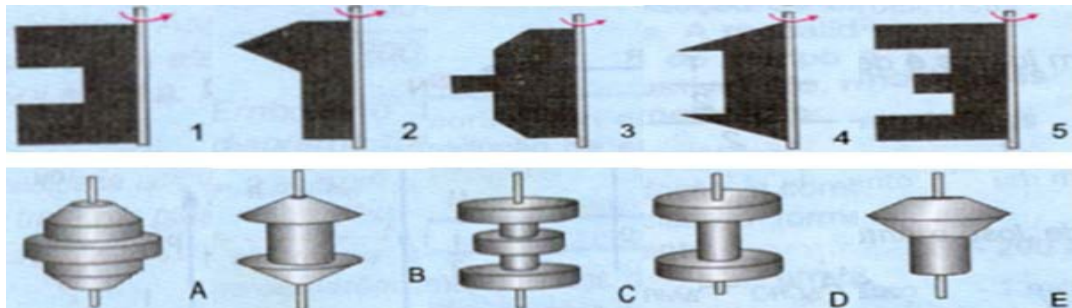


Figure 1 – Question 30, Enem 1999

b) Mental construction with representation of the idea of a solid of revolution.

Each group received the same set of objects, built with cardboard and wooden sticks, represented in Figure 2.

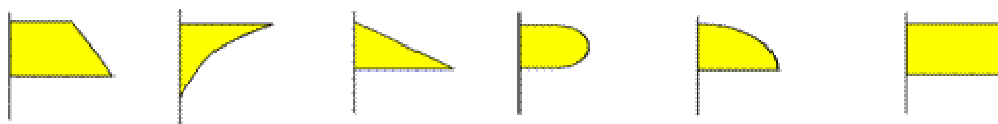


Figure 2: plans of revolution 1

In this activity, each member of the group revolved one of the objects (plane regions) around the stick (Axis of revolution), so as to recognize the solid formed with the rotational movement. When necessary, the teacher helped the group with questions, trying to get the participants to reflect and reach a conclusion. Based on this, each described the solid formed and explained to fellow group members.

This done, they drew each of solids, considering its size closest to the actual dimensions.

After this step, in an activity of creativity, inspiration and fun, each design was complemented by creating other objects that had the shapes of solids generated. So were designed witch hats, dog pots, lamps, fish tanks and umbrellas, among others.

c) Construction and planning of a solid of revolution

This step of the workshop was perceived as more complex than the previous one and encouraged the construction of a similar artifact to a prototype developed for engineering.

As in activity b, this activity involved a flat region for rotation around an axis. Each component received an object constructed with cardboard and a wooden toothpick, as in Figure 3.

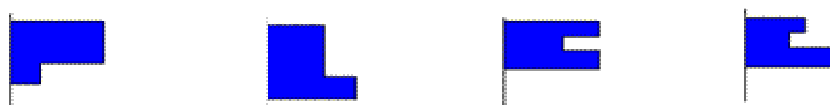


Figure 3: plans of revolution 2

The activity was to rotate the object around the axis of revolution and "imagine" the solid generated. Discussing and exchanging ideas in groups, participants concluded on how the simulated solid through this rotation.

The group also should perform other tasks. First, represent the solid generated, in a drawing, and based on solid imagined and represented, draw each of the flat parts needed for its construction. With the ready drawings, and the parts of the solid too, all components of all groups should choose among the various flat pieces available in the central room table, those corresponding the parts of the solid generated. This stage of activity could be done with the support of rulers and calculators, to select the pieces after the group concluded that the pieces chosen were appropriate to form the solid. In central table were ready cardboard cutouts of rectangles, circles and annuli in number and measures representing all parts of all solids without missing or spare parts. Finally, back to the table, the group should build the solid, shaping and joining the pieces with tape.

With the prototype of the solid ready for new interaction in groups, the challenge was then to determine the measures of surface area and volume of solid built.

As a final activity of this step, all the solids formed were exposed in the central table and a representative from each group explained to all, as was the solid, starting from the generating region and the axis of revolution considered. The calculations of the measures of surface area and the volume of each solid constructed were also presented.

d) The last activity was the return to the opening activity of the workshop.

For the closing of the workshop all groups have positioned themselves as early in two rows and the same activity of the opening of the workshop, the peer recognition of flat region and corresponding solid generated, was again proposed. At this time the pairs were formed rapidly and without difficulty to match the figures of cards.

When the workshop was applied to teachers, we requested a supplementary activity: Let each one to identify and describe a problem, or a problem situation for the application of geometry, plane or space in their area of expertise.

3 A preliminary assessment and some thoughts of who proposes the workshop

In planning activities, as reported in section 2 above, we looked for an innovative pedagogical action in the context of active and meaningful learning.

The completion of all activities required "hands on", which we understand as a condition for active and meaningful learning: do to learn, to learn to do, and to thinking about what it does and did.

In the opening activity, recognition of pairs of corresponding planes and solids of revolution, it is noted that the construction of the object occurs in thought. Without understanding how the whole and each of the parts, it is not possible to design a concept. Regardless of whether they are students or teachers, many participants had difficulties in identifying the figures so that they could relate them to each other.

In contrast, and as an assessment of the potential of the workshop for a cognitive construction at the end of the activities, it was simple for all to associate the generating regions with the respective solids generated.

The interaction for the exchange of knowledge, when it is promoted, helps everyone. In a group of studies of mathematics, the basic mathematics always plays a starring role. And there is often difficulty in several orders: recognition and application or algebraic, geometric or numerical processing. But all difficulties can be overcome, when all have a role in learning and teaching. Exchanges, discussions for a collective understanding nourish and strengthen the network of knowledge involved. This was the main outcome of the discussions on the calculation of areas and volumes of figures and solids formed. Some remembered well the formulas that could be used, others remembered some relationships, but in the end everyone understood what was said and, in different ways and attempts to explain to colleagues, the concepts of area and volume resulted naturally as measures of plans or spatial regions.

Another highlight is given to the concept of concrete materials. These are relevant for all ages and stages of school and also university. However, it doesn't mean that they should always be manageable objects or that concrete is something that we take at hands or where you can touch or even see.

According to Duval (2009), one of the important features of mathematical activity is the diversity of registers of semiotic representation it mobilizes mandatory. What characterizes the mathematical activity of the cognitive perspective and differs from the other sciences should not be sought in concepts, but in the fundamental importance of semiotic representations and the huge variety of these representations that arise in mathematics. In this case, the

geometric figures and natural language. The geometry mobilizes cognitive aspects like visualization, construction and reasoning. The coordination of these aspects is needed so that learning is meaningful, what we understand to have been contemplated, considering the activities promoted. Additionally, the four forms of significance, highlighted by Duval (2009) were used: construction and description in order to reproduce a picture; the interpretation of the shape of the figure of the geometrical point of view; the interpretation of the elements of geometric solids and possible changes of plane figures with perceptual reorganization that these modifications enable.

Each solid formed in the activities of the workshop was built before, in thought, in respect of processing ideas with imagination and consideration of the idea of the other. And so is the cognitive concrete: must be constructed and understood as active structure thoughts and then has meaning and significance.

This workshop was attended by privileged moments that allowed the interaction of disciplines with each other and with reality, overcoming the fragmentation of education and aiming the integral formation of students. Thus, we expect that they can critically engage the citizenry with a global view of the world and able to tackle complex, large and global problems of reality. We hope, really, that teachers, starting from the experiments as well as reflections and ideas discussed, can (re)organize their learning environments, taking into consideration the views and the sense of activities in the workshops.

4 Evaluation of the participating teachers

As described in section 2, the closing activity of the workshop was considered an evaluation activity, since repeated the same activity of the opening. Thus, even while monitoring each of the editions promoted, we've got some returns. Both the accompanying teachers, as students who participated, it was possible to observe learning and the ease with which the associations made by the required activity. In fact the activity has become very simple for everyone.

Besides this aspect that gives visibility to learning built, we highlight the satisfaction of the teachers which we observed during the conduct of all activities and the involvement with that accepted and overcame the challenges posed.

We had return of some schools that said that the activities have been replicated by several teachers who participated in the workshop and also by some students who recommended the activities in spatial geometry classes. Some students applied the activities at the invitation of his teachers, to other colleagues who had not participated in the workshops at the university.

For participating teachers, we had a higher purpose, especially in relation to mathematics teachers. The aim was to suggest pedagogical strategy challenges for student teams. Thus, teachers were challenged and instructed to carry out the activities in the same manner as may be proposed for their elementary students. At each step, the activities demanded involvement and, through them, the teachers drew conclusions that made it possible to systematize ideas, understand some definitions and concepts related to covered properties which were already known. Many teachers have proven surprised to realize some meanings about which they had not been questioned yet, and they "taught" as set formulas, for example, the formulas for calculating the lateral area of cylinders.

Apart from realizing that teachers welcomed the idea, they showed satisfaction to learn things they supposed knew, they were asked to answer some questions for self-assessment and other for assessing the workshop. How self-assessment teachers should respond about was individual and team performance, and about the workshop, the issues were related to quality aspects of the physical and materials conditions, as well as the potential of activities such as active and significant learning strategy about geometry concepts.

Teachers who participated in the activity evaluation, answered questions and gave returns as shown in Figure 4.

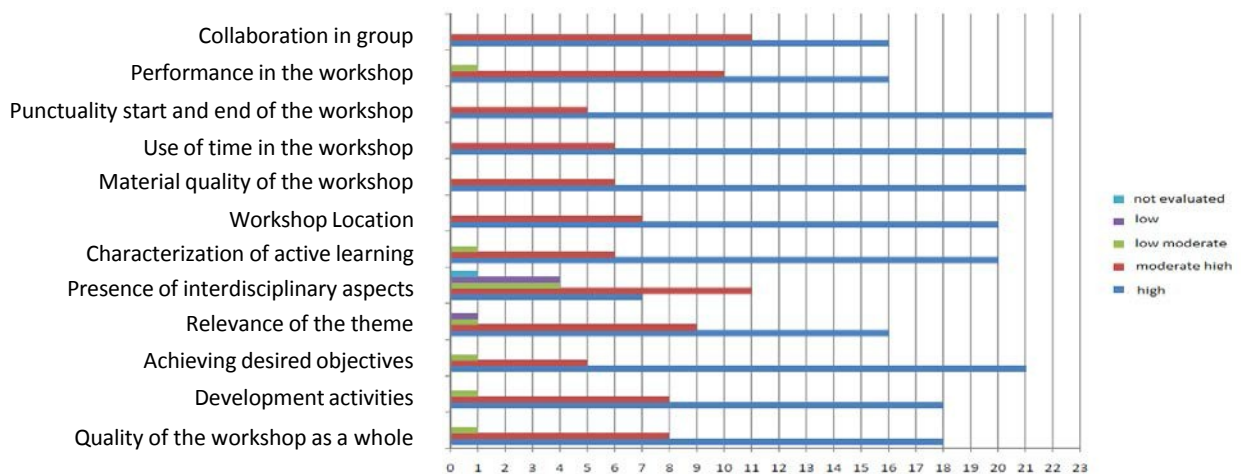


Figure 4: Evaluation Workshop on Solid Geometry

In the graphic of Figure 4, the questions were translated into categories on the left and associated with different colors, accounting for the frequency of responses that have been proposed for simple select from the following degrees: low, moderate low, moderate high, and high, beyond the possibility of not evaluate. The colors correspond to each grade are shown in the legend appearing on the right side of the figure.

As the graphic shows, interdisciplinarity was not considered a strong point of the workshop. However, in all other evaluated items, the workshop was considered high quality by most teachers.

As self-assessment, virtually 100% of teachers felt that he/she collaborated with the group and worked in the workshop with high or moderate high degree of quality, revealing a good use when performing activities.

In what regards to the time, start and end of activities, use of time, the quality of material and the location of the workshop 100% of teachers considered these conditions of moderate high or high degree.

With these grades, moderate high or high, virtually all teachers have considered the topic of the workshop relevant, that the goals have been met and that the activities were targeted and developed properly.

One of the most important aspects of the evaluation was to know the potential of the workshop as an active and meaningful learning strategy. As shown in Figure 4, and just as we had imagined, the teachers, except one, considered high or moderate high degree of quality of the workshop as an active and meaningful strategy for learning about geometry concepts.

Finally, the entire workshop received approval from the participating teachers who considered the activities and other conditions with level of quality high or moderate high. In fact, the workshop was organized to be an active learning strategy in its simpler sense like says Felder & Brent (2009) where all students are called upon to do other than simply watching, listening and taking notes. So we agree with the teachers and we consider the workshop an active and meaningful learning strategy: on the one hand means that active learning requires the action of each and, moreover, significant because only makes sense to learn if there is understanding of meaning.

5 Conclusion

The workshop themes were proposed in two directions, to expand the knowledge and support concepts in the areas of basic sciences and mathematics, and to suggest and discuss practices in high schools, in order to contribute to improving the quality of education in these areas.

We believe, like Clements & Battista (1992) that the development of spatial ability is a major aim in many guidelines for mathematics teaching. They claim that there has been a large number of theories of intelligence, which distinguish between different aspects of human intelligence, for example linguistical and reasoning aspects. And many of these theories consider the development of spatial ability as one of the most important. Spatial perception, visualization and mental rotation, all considered regarding the activities of the workshop, can be developed and contribute very much with the development of spatial ability. According Clements & Battista (1992) spatial ability is a human qualification that is relevant to a high degree to our lives, independent of our professional area.

Another component that integrated our planning and that was highlighted for the involvement was the entertainment quality of the workshop that led to the exploration and dialogue in groups and all participants in the collective closing of each proposed activity.

With Engfut project in its program of Mathematics workshops, teachers and high school students experienced processes of active learning in activities that departed from challenges, problem situations, experiments and constructions which derived meaning and significance of concepts content and skills development.

Especially, in the solid of revolution workshop topics were chosen from those that are important anchors for learning that are proposed in the subjects of Mathematics for Engineering and where students have lags, and sometimes gaps, causing discouragement by engineering course and the necessary study, when the difficulties to transpose require the resumption of large-scale of base-level content.

Interdisciplinary is constituted by a factor of personal transformation and not only in integrating theories, contents, methods or other aspects of knowledge. Integration is only one part of the process, which enables to reach new questions and new searches, for the development of understanding.

According to the teachers the results were positive and interesting. Conduct workshops, as his students, has generated new possibilities. Teachers comment that, from the workshop, feel challenged to also address the concepts through actions to be performed by students and not only for them as teachers.

Learning is, in fact, tasks and possibilities that the learner and the teacher have in its function, the vital role of promoting conditions for learning to become effective. With the proposed activities, we hope to have contributed to the interdisciplinary teacher qualifications, so that enhance their creativity in organizing situations of active learning in high school ambiances.

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Educational Game to Teach Vehicle Routing Heuristics

Jimmy Gilberto Davila Velez *

* Operations and Systems Department , Faculty of Engineering, Universidad Autonoma de Occidente , Cali , Colombia
Email: jgdavila@uao.edu.co

Abstract

The CVRP (Vehicle Routing Problem with Capacity) is a variation of VRP (Vehicle Routing Problem) that is to find a set of routes in such a way as to satisfy the demand for a certain amount of n customers located in an area geographically, this problem is considered as a NP-hard problem that consumes high computational times in solution, at which several authors have proposed the use of heuristics that generate near-optimal solutions. In the present work aims to develop an educational game to support the teaching-learning process of applying heuristic methods of savings, sweep, and nearest neighbor for solving CVRP problems, this teaching tool will facilitate the appropriation of routing principles and heuristics developed, generating a teaching-learning process based on the principles of meaningful learning, experience and constructivist

Key Words : Educational game, Logistics, CVRP heuristics.

1. Introduction

At present, the management of operations form a basic area in the development of the business strategy and in achieving sustainable competitive advantages for companies. (Luque, Lopez, & Marques, 2011) Training in the management of operations allows the student not only penetrated prior knowledge relevant and significant to the execution of a specific task, if not that in turn settle their knowledge in the development of strategies for making decisions about how to plan, organize, direct and control the activities of a company; decisions that are fundamental to add value and encourage competitiveness in the area of business development.

However, the students often consider the areas of discipline is difficult to understand and outside of his professional interest; factors such as low motivation and methodologies used by the teachers are key to that students do not perceive clearly the benefit of the subjects. (Luque, Lopez, & Marques, 2011) "The methodology used by the majority of teachers for the teaching of operations management, is specifically based on lectures, where there is no substantial interaction between the teacher and the student and the topics; basing its methodology in the removal of literature books, articles and experiences, which are transferred to the student". (Gonzalez, 2011) On the other hand other authors demonstrate various difficulties in the current forms of education, where they claim that "these methods alone do not guarantee completely the formation of the abilities needed in future professionals for the creative solution of social problems and productive that occurs every day". (Echeverri & Rodriguez, 2010) (Luque, Lopez, & Marques, 2011) And others believe that the current methodologies in the students generate insecurity and low participation due to the fear of being wrong, there was little motivation and a poor perception of learning, which makes the understanding of the subject matter and the topics covered. (Yturalde, 2012) For its part says that traditional methodologies are a rigid method in design, and development goals, in which the student performs the exercise that prompted without knowing the reasons why it is done well and not the other way. Finally it is considered that in the traditional methods of teaching the memorization and repetition are the central axis to generate learning in the student; where the teacher plays an active role and in most cases the student a passive role, creating in this academic units and limiting factors in its development.

The proposal presented in this document, is the development of a learning game applied to the area of logistics belonging to the administration of operations, serving as a didactic tool complementary to the traditional processes of the teaching of the subjects of routing of vehicles, In particular to the methodologies of solution of problems of CVRP (routing problem Vehicles with Capacity), developing learning processes, significant, constructivist and experiential where students and teachers through the game develop their processes of teaching-learning with greater interaction through active methodologies.

2. Theoretical Framework

The routing problem vehicles (vehicle routing problem, or VRP) is a problem that begins in a warehouse or central warehouse which has a fleet of vehicles and must meet a set of clients scattered in a geographic area.

The objective of the VRP is to deliver goods to this set of customers with demands known, at minimal cost, finding the optimal routes that originate and terminate in the warehouse. All customers should be treated only once, for which they are assigned to the vehicles that will bear the burden (demand of the customers that visit) not to exceed its capacity.

Within the special problems of VRP to resolve this CVRP, Routing Problem Vehicles with Capacity, which is a routing problem vehicles where the capacity of the fleet becomes restrictive for the formulation. The target function of CVRP minimizes the total cost to take to all consumers. In this type of problem, consumers have a deterministic demand; all vehicles are equal and out of a distribution center.

The variables involved in the approach to a problem of CVRP are: The number of customers, the location of its customers, the distribution centers or deposits, the capacity of the vehicles, the demand of the customers, the travel times, the costs of transport, and description of the pathways of transport

When the cost to go from one center to another consumption i center of consumption j is equal to the cost of going from the center of consumption j to the center of consumption i the problem is called CVRP Symmetric CVRP, SCVRP) otherwise is called Asymmetric CVRP

The problem of routing of vehicles with capacity (CVRP) is a problem of combinatorial optimization, of type NP-Hard; this means that the effort of computing necessary to find an optimal solution grows exponentially with the size of the problem. For this reason are used to approximate methods so that you can find good enough solutions in a reasonable computation times.

The CVRP consists in finding a series of routes in such a way that meets the demand for a certain amount of n clients distributed in a geographic area. The sum of the distances travelled by vehicles must be kept to a minimum. Each vehicle part of a warehouse to visit the n clients and must return again to the, is considered a homogeneous fleet of vehicles, that is to say, all vehicles have the same capacity.

The heuristic methods began to be developed between 1960 and 1990, on the other hand, growth of the heuristic methods goal has occurred in the last two decades. One of the classical methods and still applicable belonging to the group of heuristic, performed a limited exploration in the space of solutions. Produce reasonably good solutions with modest computing times, are more flexible, simple and easy to understand that the meta heuristic.

Over time a great variety of methods for the solution of CVRP. These can be classified into exact methods, and approximate methods (Meta heuristic and heuristic). The exact methods are those that provide an optimal solution of the problem through an effective algorithm, are of great functionality for problems up to 50 tanks where there are few customers. For problems with a large number of customers, they can spend long times in its computational solution, what makes in these occasions are you prefer find an approximate solution and not the optimal use methods based on heuristic and Meta heuristic.

Below are some of the most commonly used heuristic methods for the solution of the CVRP. The Savings algorithm of Clarke and Wright, (Rocha & González, 2011) It is one of the most widely used for troubleshooting routing of vehicles with capacity. This calculates the greater savings in distance, use the arches. (Walls, 2011) If a solution in two different paths $(1, \dots, i, 1)$ and $(1, j, \dots, 1)$ can be combined forming a new path $(1, \dots, i, j, 1)$ as shown in the figure 1, the savings (s_{ij}) (in distance) obtained by the union is:

$$(1) \quad S_{ij} = C_{oi} + C_{oj} - C_{ij}$$

Since the new solution the arches (i,o) and (o,j) not to be used and add the arch (i,j)

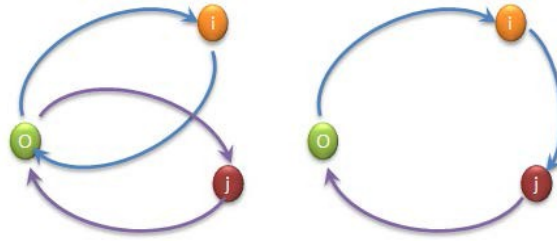


Figure 1. The savings algorithm
Source: The Author

The savings algorithm has been popularized quickly and growing due to its simplicity to be implemented, (Ballou, 2004) The comparisons with the optimal results for small problems, with a limited number of restrictions, have shown that the assessment of the method generates solutions that are, on average, 2% of the optimum.

The sweep or sweep heuristics. (Wren, 1971; Wren and Holliday, 1972; Gillett and Miller, 1974), (Daza, Montoya, & Narducci, 2009) the clusters are formed by rotating a semirecta with origin in the warehouse and incorporating customers "swept away" by such semirecta until it violates the capacity constraint. Each client is given by its polar coordinates (p_i, θ_i) where θ_i is the angle and p_i is the length in a straight line from the origin point to the customer in a system that has the warehouse as the source. Each cluster is then routed by solving a TSP (traveling salesman problem - Problem of the Traveling Agent) The procedure is repeated n times, beginning in each run by a different client to the manner in which the clusters are generated; routes learned do not overlap, what may be good in some cases. This algorithm can be applied in problems planes, that is to say, in which each node corresponds to a point in the plane and the distances between them are defined as the Euclidean distance or, failing that, distance of Manhattan. (Ballou, 2004) for certain types of problems; the precision is projected to produce an average error rate of approximately 10 %.

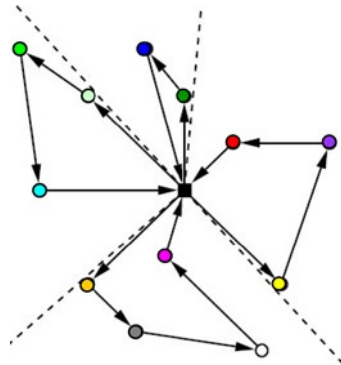


Figure 2. The sweep heuristic
Source: The Author

The nearest neighbor algorithm, (Pinto & Delgado, 2010) was first introduced by J. G. Skellam, which used half of the observed distances to determine if the data are grouped together. The bulk of the work done for this algorithm was made by P. J. Clark and F. C. Evans in 1954.

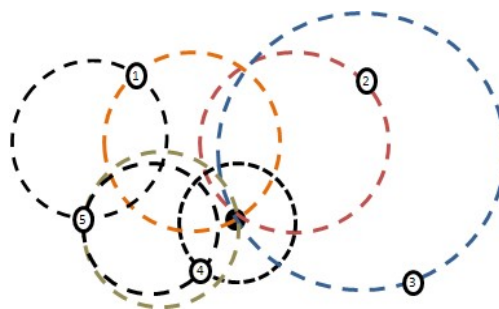


Figure 3. The nearest neighbor algorithm
Source: The Author

This algorithm determines a solution based on the closeness of location, to join a group of clients distributed in space. The algorithm is to go about building the routes in a sequential manner, choosing as next node, the node closest to the current node, starting from the warehouse. The inspection of the closeness of the nodes, is done in an iterative fashion, and in each step, examines the vicinity of the current node for the election of the node to be inserted in the path. It is part of the node (client) closest to the warehouse. Once located in the node closest to the warehouse, inspects the vicinity of this node to find the nearest to him, and check the restrictions associated with the CVRP. If you meet these restrictions on capacity, now the vicinity to inspect will be the vicinity of the current node or last node inserted in the path, and repeat this procedure up to insert all the nodes of the problem. When you insert all the nodes terminates the path returning from the last node inserted until the warehouse or starting point.

3. Competencies to be developed

The themes to develop in the learning game is the application of heuristics for the solution of problems of CVRP (routing problem vehicles with capacity), applied to the design of transport routes and distribution in the logistics area.

Some of the competencies that you expect to develop with the implementation of the learning game are:

3.1 Learn to know

Identifies the differences between the problems of VRP and of CVRP to raise solution methodologies appropriate to each type of problem according to their complexity.

3.2 Knowing how to do with sense

Identifies and analyzes problems in designing alternative solutions to engineering problems, using the knowledge acquired in their discipline, and integrating them with the resources available for the purpose of seeking to improve their environment, in the framework of ethical conduct, legal and environmental.

Uses Cartesian coordinates to locate positions on the Cartesian plane accurately.

Heuristic applied to the solution of problems of CVRP of systematic and appropriate manner.

Applies the design criteria of routes to the solution of problems of transport in an appropriate manner.

3.3 Action - Acting - Creating

Defines criteria for the comparison between the results of the heuristic applied to the settlement of the problems of CVRP to take appropriate decisions applied to a particular problem

3.4 Know how to be and live

Follow instructions of the proposed methodology for the development of the educational game in an orderly and precise.

Works in collaboration with other in a respectful, responsible and efficient, for the development of joint activities and projects, raise their own ideas and recognizing the value of the contributions of other members of the team, contributing to the solution of problems of the social environment, production and service.

4. Methodology

Below are shown the methodology to be followed for the completion of the game:

4.1 Moments of Intervention

Table No. 1 Moments of Intervention

Activity	In Charge Of	Time
Motivation	Facilitator	5 min.
Orientation	Facilitator	10 min.
Development	Participants	60 min.
Conclusion	Plenary	10 min.
Close	Facilitator	5 min.

Source: The Author

4.2 Develop

The development of the game is divided into five main stages:

4.2.1 Presentation of the Case

The facilitator will present the case to solve, corresponding to a problem of CVRP with a distribution center and n nodes that will be the customers.

Each distribution company (team participant) should locate in the game board the coordinates of the center of distribution and the corresponding nodes to each customer.

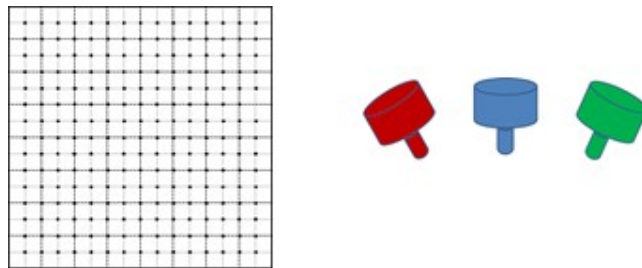


Figure 4 Game Board and 3 nodal pins

Source: The Author

Both the node as customers should be indicated nodal pins with distinctive color.

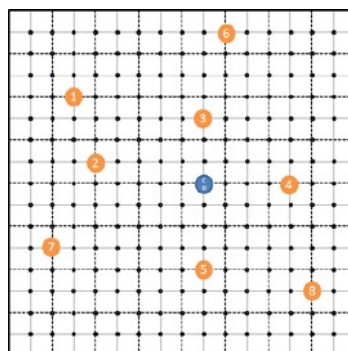


Figura 6. Game Board with CD and nodes of clients located

Source: The Author

For the stages 2, 3 and 4 must be to make use of the bead and the tape measure for measurements of distances corresponding.

4.2.2 The Savings algorithm

Step 1. Calculate the number of savings to calculate.

$$(2) \frac{n!}{2} = \frac{n!}{2} = \frac{n(n-1)}{2}$$

Step 2. List to calculate the savings in the Format No. 1

Step 3. Measure the savings for the routes (0, i, 0), (0, j, 0) for each pair of customers i and j according to:

$$(1) S_{ij} = C_{0i} + C_{0j} - C_{ij}$$

Step 4. List the customer pairs (i,j) in decreasing order of its values of s_{ij} savings.

Step 5. Consider the S_{ij} maximum, to assess the capacity constraint, if it is, to include the customers i and j, in the path. Eliminate S_{ij} of future considerations.

Step 6. Evaluate the following maximum saving of the list and repeat step 5 until it meets the restriction on the capacity.

Step 7. Build the route with the nodes included in steps 5 and 6. Designing the route in accordance with the general principles of design of routes exposed.

Step 8. Repeat steps 5, 6 and 7 until you cover all the nodes.

Step 9. Calculate the total distance travelled in the sum of all the routes.

4.2.3 The sweep heuristics

Step 1. Sort the θ_i customers according to approximate way of growing.

Step 2. Tie the cord to the pin that defines the warehouse, and draw a semirecta directed toward the north, perpendicular to the position of the same.

Step 3. Sweep the nodes with the cord in the anticlockwise. Evaluate the demand sweep of the first node, if it meets the capacity constraint; include the node in the path.

Step 4. Repeat step three until collected demands of nodes including meets the restriction of capacity

Step 5. If two clients have the same value of θ_i , first put the lower value p_i .

Step 6. Build the route with the nodes included in steps 3, 4 and 5. Designing the route in accordance with the general principles of design of routes exposed.

Step 7. Repeat steps 3, 4, 5 y 6 and 7 until you cover all the nodes.

Step 8. Calculate the total distance travelled in the sum of all the routes.

4.2.4 The nearest neighbor algorithm

Step 1. Be placed in an initial node of the warehouse.

Step 2. Take the distance from the warehouse to each and every one of the remaining nodes not included on any route.

Step 3. Choose the node that has the least distance in relation to the last added node, if your demand does not breach the capacity restriction include it in the path, this node will be the new starting node.

Step 4. Repeat step 2 and 3 until the collected demands of the nodes included in the path meets the capacity constraints.

Step 5. Build the route with the nodes included in steps 2, 3 and 4. Designing the route in accordance with the general principles of design of routes exposed.

Step 6. Repeat steps 1 to 5 until covering all the nodes.

Step 7. Calculate the total distance travelled in the sum of all the routes.

4.2.5 Contrast of Solutions obtained with solution of a Routing Software

In previous paragraphs, it is mentioned that the problems of CVRP, where required in the settlement include more than 50 nodes, are converted into problems with consumption of large computational times, taking into account this condition the cases used in the development of this playful does not violate this condition and make it possible, compare the response obtained in each one. With a computational solution. For this contrast will be used the software Logware 5.0 , router module (Ballou, 2004), with which you can solve the problem of CVRP using partially the tools offered by the software.

Once settled the case with the software you need to calculate the percentage error between the proven solutions.

5. Resources

Table No. 2 Materials

Material	Amount	Unit
Game Board	4	Unit
Colours Pins	100	Unit
Formats	20	Unit
Metric Tape	4	Unit
Cord	16	Unit

Source: The Author

Table No.3 Participants in the Activity

Participants		Role	Activity
Minimum	Maximum		
4	8	Head of Distribution	Responsible for defining the routes according to the methods and restrictions set forth
4	8	Distribution Assistants	Responsible for performing calculations of distances and costs

Source: The Author

For the development of the activity is required of a living room with availability of dashboard, beam and video with the following suggested provision.

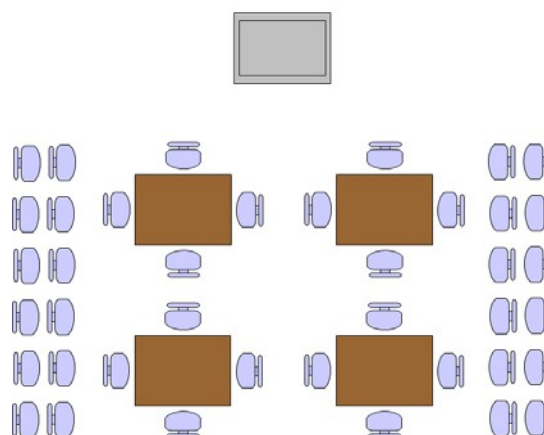


Figure 7. Provision of physical space suggested

Source: The Author

6. Conclusions and Recommendations

Educational games are converted to support tools in the processes of teaching-learning, that allow you to enhance the interactivity between the teacher and the students in the classroom, through the development of meaningful learning, experiential and constructivist.

The use of educational games in the processes of teaching and learning, enable the development of transferable skills and professionals in the students in training.

In the consulted literature revealed the existence of few teaching tools type educational game, that support the teaching-learning process in the area of logistics, so it becomes this deficiency in a wide choice of research.

The implementation of this playful manages to make the process of understanding the development of heuristics proposed in the students that the running, the effectiveness of this understanding can be measured using formal tools and/or informal constructivist evaluation

The practice has been implemented in the course of Integral Logistics, with very good results in the learning of the techniques, versus the levels of learning obtained in the courses where they have not been used.

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Engineer for a day: interdisciplinary activities for high school

Roselice Parmegiani*, Carla Eliana Todero Ritter*, Henrique Tramontina*, Andressa De Ré*,
Vera Lúcia Barni Capoani Balestrin*, Fabiano Ramos Rodrigues*, Luciano Salerno*

*Technology, Nature and Exact Science Centre, Universidade de Caxias do Sul – CARVI, Caxias do Sul, RS, Brazil

Email: rpchies@ucs.br, cetritter@ucs.br, ike_bg@hotmail.com, are@ucs.br, vlbc bale@ucs.br, frrodri1@ucs.br, lucianosalerno75@gmail.com

Abstract

The present article aims to describe the project “Engineering for a Day”, developed at UCS-Bento Gonçalves campus, which has the objective to raise scientific vocations to the High School pupils and also the interest by the exact areas’ college courses, mainly the Engineering ones. The activities of this project, performed in sequenced stages, outcome in the “creation” of a remoted control for a toy car. The pupils join in the whole process in a dynamic and joyful way, interacting and experienced the Academic environment. Moreover, they can establish a bond between the practical life situations and school content.

Keywords: engineering; interdisciplinary; hands-on activities.

1 Introduction

The college institutions overall, has the concern to capture potential pupils for its courses. Related with Engineering courses, beyond the enrollment of candidates with a basic and solid formation, there is an urgent necessity to graduate more and better professionals. Although, attract pupils for engineering courses is such a hard task, since these courses are usually labelled as quite difficult and beyond the reach for the minority. In other words, bright pupils with excellent background at the exact subjects, especially on Mathematics and Physics. These curricular components, which are considered real obstacles for the candidates to College

Unfortunately, most of the cases the Mathematics, Physics, Chemistry and Biology classes are quite theoretical and decontextualized, with few or none practical experimentation. The school activities sum up on the teacher’s lessons and exercises lists. Therefore, pupils generally misunderstand and barely realize the utility of the taught contents; they just mechanize calculus process and apply them in hypothetical situations, most of the situations quite resemblant with the given example as model.

However, preparing High qualified professionals to the world, able to interact with their pairs, based on knowledge and technology should be the main goal of all teachers, regardless of area which they work. For that to occur is needed to modify teachings strategies and pursue alternatives for a real efficient teaching process. Pupils need to learn and acquire necessary competences for teamworking, researching, investigating, creating and solving problems.

According to the National Curricular Parameters (PCN) for high school (Brazil, 2002), The Learning-Teaching process should as always as possible aims problematized and concrete issues, which stimulate the pupil to think, plan, find solutions and work in groups to develop his autonomy. The document sustains interdisciplinary and emphasizes the process comprehension, facing problems and construct discussions and elaborate propositions are competences to be reached in high school.

According to Fazenda (1979), The Interdisciplinarity characterizes by the cooperation among disciplines in order to exist reciprocity in knowledge readings for a mutual enrichment; presuppose a change of attitude towards knowledge, which breaks barriers and also the knowledge fragmentation areas. Paviani (2008) states that there are many ways to create interdisciplinarity, whether “at new knowledge development, at the knowledge systematization already developed, teaching activities, conference’s elaboration, and organization of teaching material for the teaching and also at professional activity” (p. 55).

It has noticed that the interdisciplinarity of scientific and mathematical learning neither dissolves nor cancels an unquestionable disciplinarity of knowledge. The specificity degree effectively presents at distinct sciences, as also at the associated technologies, would be quite hard to learn at elementary school, being naturally reserved to High school. Moreover, the scientific disciplinary knowledge is as so essential part of contemporary culture that its presence at basic education and, consequently at high school is quite unquestionable (Brazil, 2002, p.6).

However, to practice the interdisciplinarity is quite hard for teachers whom, historically, do not surpass the established boundaries to the curricular component which it has been taught. Modifying the Learning-Teaching process demands an organized curriculum, not on the basis from logic that structures sciences, but on situations which learning makes sense for the pupil in order to provide them instruments for dealing in different contexts and also in unpredictable situation in his life (Albino, 2009).

The contextualization becomes learning much more significant to the pupil because maintains close relationship with its daily routine, its living experiences, its previous knowledge. According to Libâneo (1998), the teacher needs to enjoy the richness of external information, reorganize them, orientate discussions and provide a critical and ordered reading. The cultural input received from means of communication and from other educational practices makes a synthesis between formal culture and pupils' experiences. The author asserts that his idea in order to transform school into a space for synthesis between experimental culture which occur in families, neighbourhoods, cities, etc. and its contents. Television and its means of communication come into classroom, even without teacher's participation. Therefore, the school should connect itself to the rich educated practice coming from informal contexts.

Ausubel, in his Significant Learning Theory states that "the most important isolated fact influencing the learning is that which the apprentice already knows" (Moreira&Masini 2001, p.17). For Ausubel, significant learning is a process which through new information interacts with the contexts inside the mental structures of the pupil promoting organization and interaction of this information in the cognitive structure. The significant learning presupposes that knowledge soon to be learned must be potentially significant for the pupil and in doing so, Hemanifests willingness to do so (Moreira&Masini 2001). Another important point which the theory states is the man constructs meanings in a better and more efficient way when considers, from beginning the learning of the most general questions about a subject instead of aiming to the most specific questions. Therefore, the most general concepts fit as anchors to the subsequent learning.

According to Ausubel, the initial problem of learning consists at the acquisition of knowledge and also establishment of inter related ideas which constitute the structure of this knowledge. The issue about learning in classroom is at the using of resources which facilitates the capture of conceptual structure of content and its integration to the cognitive pupil's structure, turning him a significant material (Moreira&Masini, 2001, p.47).

Tavares (2008) states that when the apprentice faces himself with a new set of information He is able to decide to absorb it in a literal form and, in doing so, his learning will be mechanic. The subject will only be able to reproduce knowledge and will not be able to transfer learning into other contexts' situations. However, when is able to make connections between the material which is being presented and his already consolidated knowledge will be constructing meanings for these information, and transforming them into significant knowledge.

On the other hand, the local and cultural experiences of the pupils need to refer to a wider context, scientific and technological. Related to concrete issues is needed to create procedures to help pupils in order to create concepts and develop competences. In this meaning, Pinheiro, Silveira, &Bazzo (2007) states that, in a modern and technological society like ours, is indispensable the fact that knowledge turns back into the science and technology comprehension. Because of it, the routine's problems proposition and the knowledge widen to solve them can and must be practiced in classroom. To focus in the Science Learning teaching process, society and technology, pupils and teachers start to research together, produce and construct the scientific knowledge that has been considered inviolable.

Related to pedagogical area, it means to break with the traditional concept which predominates at school and promote a new way to understand the knowledge production. To dismistify the neutrality spirit of science and technology and also face the political responsibility of them. This surpasses the mere repetition of teaching of laws that rule the phenomenon and possibilitate to reflect about the social and political usage which has done with this knowledge. Pupils receive support for questioning, developing imagination and fantasy, abandoning the state of subservience toward the teacher and presented knowledge in classroom (Pinheiro, Silveira, &Bazzo, 2007, p. 77).

Santos (2007) supports the scientific literacy while social practice and states that an elaborated curriculum under the scientific literacy gives more sense to the knowledge which are being used with an hermetic language and also in a decontextualized form, reproducing a false image of science. According to the author, as long as it is not create a following way to surpass the current usage of science, the scientific education will continue limited to a precarious education. Shamos (1995, apud Santos, 2007) states that a literate person is able to not only master the reading of scientific vocabulary as well as he is able to read, discuss, talk about it and write coherently of a significant way in a non technical context. According to him, pupils should have a wide knowledge about scientific theories and being able to propose models at sciences.

Although, the conception of technological-scientific learning intended is quite different from that one which has been done in most part of our schools. Nevertheless, is possible to implement it when teaching Mathematics, Physics, Chemistry, Biology and the related science technology. For this matter, both school and its community need to mobilize and evolve themselves in order to produce new work conditions to promote a real educational change (Brazil, 2002).

2 The foundations of project

In order to pursue alternatives to offer both public, private high school pupils a set of integrated and applied activities which stimulate creativity, teamwork, the pursuit of solution that can awake the taste for science and engineering, the project so-called "Engineering for a day" was born. A remote controlled toy car was the chosen object for being work support, since cars in general wield fascination in children and adults of both sexes. Initially it had been thought as activities which would result at fairing modeling of toy car and also the manipulation of electric chassis. Many studies and experiments were done to allow the implementation of such proposal and being permitted to be performed in a class shift, it has decided to add described activities in the chemical laboratory for the polyurethane production, as chosen material for being used at the toy car fairing.

A concern from the proponent team was about how to find connections in those works with school contents, to allow pupils to apply their knowledge. Therefore, the first activity which consists in expanded polyurethane (PU) produced in laboratory, demands knowledge in chemistry. Overall, people interact with chemical knowledge in different ways, whether by acquired knowledge or popular beliefs. At school, overall, pupils get along on chemical knowledge essentially academic which occurs mainly by transmission and memorization of information (Brazil, 2002). It is emphasized periodic properties, classifications, types of reactions and solutions, isolated knowledge with no bonds on pupil's life.

In order to permit a world reading taking account the first project activity, many products derived from polyurethane are presented to pupils, such as, foams, plastics, tints, sealing products, tires, etc. It is established a dialogue with the group in order to rescue knowledge topics about the subject and also investigate the knowledge about school contents related to polymer. In doing so, it is an approached subject related to chemical reactions, types of reactions, urethaneic links, reagents, density and the form of discarding polyurethane to reduce damage on environment. Moreover, pupils receive explanations about protective equipment to use in laboratory and reflect about the matter of chemical and environment engineer to the breakthrough of science.

In struggle for surviving, human being extracted and synthesized matters from Biosphere, Hydrosphere, Lithosphere and Atmosphere. In these processes, He affected his environment, modifying and degrading it. So, the contents to be approach in this phase should refer to the extracted and synthesized matters by Human being. As well as the introduced matters in environment due to usage and manufactured process. It should point the economic, social, and political implications on industrial and Agricultural products (Brazil, 2002, p.35).

The fairing modeling of toy car, second developed activity, uses technical projects developed by students from various Engineering graduation courses and elaborate at the technical drawing subject. Students and teachers are mobilized in order to contribute with actions to turn the Engineering more concrete and applied, and also, to help diminish the evasion of students. Besides, in general, such projects offer pupils from high school little complexity, since the graduated students are normally at third semester of their courses. The possible "errors" in the fairing projects characterize in problems which students must solve during its performance.

The modeling is done in a standardized PU block and demands mathematical knowledge, specifically numbers, geometry and measures. To keep up with work is necessary to have notions of scales, orthogonal views, measurement units, angles, geometric figures and correct usage of measurement instrument. The fairing, which is modeling in groups of three and four pupils, is being constructed from a previous study of the project and a joint discussion regard to its details. The individual knowledge is being socialized in search of ways and solutions to cope with the challenge.

In its formative role, Mathematics contributes to the development of thought process and attitudes's acquisition, whose utility and reach transcends the own mathematics' ambit, forming capacity to the pupil to solve genuine problems, generating investigation habits, providing trust and disengagement to analyse and face new situations, propitiating a new and wider scientific view of reality and from others individual capacities (Brazil, 2002, p.40).

The mathematics related to the production of fairing has an instrumental character because it provides a set of indispensable techniques and strategies to its execution. Overall, is necessary that the pupil realizes what the study of mathematics allows it to use numbers, Geometry, Statistic, Algebra and probabilities as tools to analyse and

comprehend phenomena linked with aplicações in the world. To master these tools' set is primordial for any engineering.

As well as at Chemistry and Mathematics, the teaching of Physics has been frequently promoted at school, upon request formulas, laws and concepts presented in a distant and disjointed way and benefits abstraction since the first moment (Brazil, 2002). Unfortunately, the usage of formulas in artificial situations and the resolution of repetitive exercises are constant practices in Physics teaching. Once it is reinforce the idea about what is necessary to promote a contextualized teaching and its meaning at the moment which is studied, and not subsequently.

Ausbel defines rote learning as being learning of new information with few or none interaction with existent relevant concepts at cognitive structure. In this case, the new information is stored in arbitrária way. There is no interaction between the new information and the one already stored whatsoever (Moreira, & Masini, 2001, p.18).

For the chassis manipulation, third activity of Project, pupils work in the Eletric Engineering laboratory and revise physics knowledge. The toy car's chassis is used to explore knowledge about electricity, electric circuits, electric current, voltage and energy source, indispensable knowledge for both electric and electrician engineering. Toy car as a whole it can promote pratical mechanical knowledge, such as forces, motion, speed and acceleration.

The three proposed activities have as strategy to explore general knowledge in order to particularize them. Typically a sequential organization of contents, at school, occurs from upside down, from micro to macro. Ausubel asserts that the most general and inclusive phenomena must be presented at first moment in order to fit as anchors for subsequent learning (Moreira&Masini, 2001).

3 The project

The project itself is thought about allying interdisciplinarity, concrete situations, teamworking, ludicity, significative learning and enchantment by Engineering courses was created the "Engineering for a day" project, which proposes sequenced activities at University laboratory in order to "produce" remote controlled toy cars battery powered. The project "Engineering for a day" is diffused, through press folders and from media to all regional and comprehensivenesshigh school and is also destinate to all second year pupils from high school. The schoolsinscrevempreviamente its classes in established dates in an annual chronogram offered by institution. The team which work on project attends one class at maximum thirty pupils, in each one of available dates in calendar. The activity itself takes approximately three hours.

The applied pupils participate in four pratical tasks, which are, elaboration of expanded polyurethane (PU), toy car fairing confection, chassis manipulation and toy racing cars. To viable to project execution, are acquired at stores remote controlled toy cars, ledsavulse and batteries. In each toy cars are used the chassis, antenna and remote control.

When the groups arrive to the institution, they are hosted and soon after participate in a round of conversation about the importance of science's studies, the engineering's role in society, work's objective and step sequences to be soon done. After, the class is divided into groups of three or four components each, who work in groups until the end of project.

Next, the groups are conducted to chemistry laboratory where they perform the first step of work:expanded polyurethaneproduction (Figure 1). In this place the usages ofpolymerin industry are approached, discarding and recovery and, after, begin an experiment to produce polyurethane a partir da chemical reaction of polioli and isocyanuratcomponents. The groups model thepolymerinside a surgical glove which is used to give a playfully character to the experiment (Figure 2). Therefore, in few minutes, the mixture expands and solidifies itself. The chemical reactions involved in the UP production process are also described in this occasion.



Figure1 – Poliurethane production experiment



Figure 2 – Modeling Poliurethane in a surgical glove

In the sequence, pupils are conducted to the models and mock up laboratory for the toy car fairing modeling. In this place they receive a PU block with patterned measures and choose one among various technical fairing projects. The projects are developed by graduation students from engineering course at technical drawing subject which is part of their curriculum.

The PUBlocks have a previously machined base in chassis shape for having the joining of chassis' fairing. In possession of both block and project, it is began the bodywork modeling of toy car using ruler, pencil, square protractor, and tools, such as, saws and sandpapers (Figure 3). Scales, measures notions and orthogonal projections are some of the required knowledge for the task execution. In the same laboratory the tints to be used at fairing painting are chosen. Different colours of fast dry spray ink, masks and gloves are available to the groups to be used at painting booth (Figure 4).



Figure 3 – Toy car's fairing modeling



Figure 4 – Painting of toy's car fairing

The third step occurs in an Electric Engineering laboratory. A technician explains to the groups how to manipulate wires, pliers, weld and leds (Figure 5). Important notions of electricity, electric circuits are discussed in this phase. After the joint of antenna, chassis and fairing, the batteries are put in the toy cars; these ones are able to drive and also turn on the headlights manipulated by remote control, which also has batteries. Hot glue is used to joint parts and adhesive the toy car with project's logo (Figure 6).



Figure 5 – Activities at the Electric Engineering laboratory

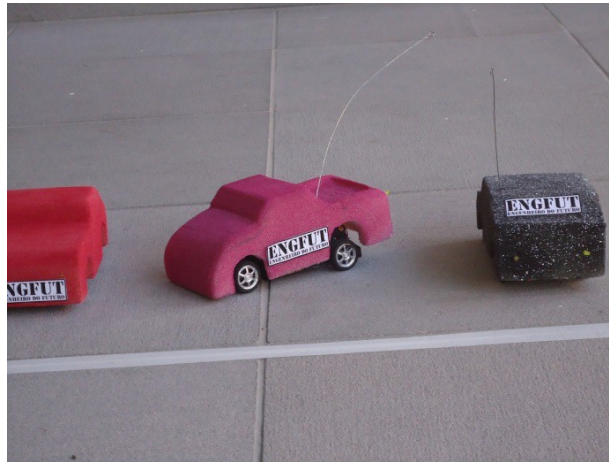


Figure 6 –Final version of toy car

In the end, pupils participate in a toy car remote control race in a raceway created for this purpose (Figure 7) and as a prize, they are allowed to take their prototypes home.



Figure7 – Racing toycars

4 Conclusion

The reached results with the project are quite encouraging, starting with the interest and adhesion of school since the offered openings were closed in the first month of diffusion. Each year is attended approximately six hundred pupils. It is visible the excitement of them of all stages. Participation is massive in order to produce the best toy car expected. It is quite common hearing manifestations such as “it was one of the best ever activity which I have done in all high school” or “it was so good that I did not realize the time had passed” showing the enchantment about the whole project. The teachers, in turn, supervise the works and are able to implement different teaching strategies for the curriculum component which they teach. The masters are admired themselves due to interest and disengagement of all their pupils.

The connection of studied contents at school with the performed activities is explored by teachers and technicians whom develop the works. In a practical and pleasurable way pupils are able to establish relations and visualize practical applications related to subjects already studied. Unfortunately it can be detected the lack of practice of the pupils toward laboratory's activities and in many times, difficulties in basic contents that certainly have been studied. One of the explanations for such difficulties is the lack of interest of pupils while effective participation at the Learning-Teaching process. The absence of a bond between the learnt knowledge at school and pupil's routine can be the main responsible by the lack of motivation and also detachment among teachers and pupils.

The contents teaching done in each step which is quite private, works very well and gives feedback and meanings to the inherent concepts toward proposal activities. Thus, for instance, the derivated polyurethane product which are pupil's knowledge to specify notions about chemical reactions, chemical and urethetics connection. Other positive point to highlight is the presence of contextualization and interdisciplinarity that are inserted in project overall.

It is worth to emphasize the involvement of engineering course students in this activity, since the same ones do the fairing projects in their technical drawing subject. Such curricular component occurs, generally, at the third semester of these courses, a stage that concentration of disciplines still predominates. It has been observed the dedication from graduation students in order to offer projects with different types of toy cars which can please the ones who might execute them.

The groups' activities contemplate many stages from the productive process evincing the dynamic character of technological area knowledge. In the opposite way about the sequence in most of schools which the proposed tasks are uninteresting and boring, the project helps to stimulate pupils the taste for science and technology. In this way, it is intended to promote the scientific literacy which is necessary in the current context (Santos, 2007).

To the teachers who work with high school pupils is given an opportunity to experience quite different work strategies from those ones that are normally proposed. Libâneo (1998) asserts that teachers will only change their way to teach, when they experiment new ways to learn. The teacher has the opportunity to rethink his practice, and at same time detect different possibilities that can come to be adopted to qualify the Learning-Teaching process. The success of project can reach with pupils may be a stimulus for masters In order to invest in uninterrupted continuous formação, opening spaces for studying, trading of ideas and organization for challenging and new teaching practices.

Another positive point is the possibility to develop the whole project, in approximately three hours of work. One class shift is perfect able to be transferred to the Academic environment. It is worth to emphasize that the "Engineering for a day" project is inserted into a wider propose, the ENGFUT – Engineer of the future project – institutionalized by UCS, and which is supported by Cnpq, Finep, Seduc RS and other companies of the region.

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Innovation in the Learning Process: Active Learning in the context of Electrochemistry

Ivete Ana Schmitz Booth*, Giovani Luis Rech*, Mário Vebber*, Valquíria Villas-Boas*

*Centro de Ciências Exatas e Tecnologia, Universidade de Caxias do Sul, Caxias do Sul, RS, Brazil

Email: iasbooth@gmail.com, giovani.luis.rech@hotmail.com, mario.c.vebber@gmail.com, vvillasboas@yahoo.com

Abstract

The engineering professional fields require engineering schools to broaden their traditional curricular structures, hastening students' actions towards a context of real situations. Active learning strategies may bring the academic world and the professional world closer together with real problems from the engineering professional practice. In this paper, a workshop is described in which problem based learning is used as the active learning strategy that should help to understand the new demands of engineering, and through which we intend to train autonomous engineers, with the ability to intervene significantly and to work as a team to solve problems. The results achieved by carrying out this workshop allows to highlight the innovative potential of problem based learning as a process through which is possible to overcome positivist teaching processes for processes focused on developing significant skills and professional competences for engineering education.

Keywords: active learning, significant learning, problem based learning, electrochemistry workshop, skills and competences.

1 Introduction

To develop structuring apprenticeships in the teaching and learning process is not just reporting on the contents provided in teaching programs. It is necessary to create mechanisms to develop skills and intervene significantly in this process. These characteristics are almost nonexistent in the educational environment, as well as unfamiliar to most teachers and students (Booth *et al.*, 2008).

Acting in training the future engineers involves predicting conditions so that they can deal with real situations, achieving relevant results with respect to their professional field. It is necessary for these future professionals to be capable, not only to execute instructions, but to create and to perfect new and better possibilities of interaction, producing significant results to the environment into which they are inserted.

In this context, active learning strategies have great potential to bring the academic world closer to reality. They have the development of students' autonomy as starting point, focusing on learning and prioritizing educational situations that involve real problems. Many authors, (Brodeur *et al.*, 2002; Sridhara, 2005; Faland & Frenay, 2006; Graaff & Kolmos, 2007; Du *et al.*, 2009; Pascual, 2010), have been declaring the pedagogical strategies of active learning, such as Problem based Learning (PBL) and Project based Learning (POL or PjBL), as natural methodologies for engineering education, since these methodologies fit very well in the engineering practice.

Problem Based Learning (PBL) allows problematization, selection of structuring and contextualized contents to support the learning of "contents", development of skills, and relevant actions in the future engineer practice. According to Charlin *et al.* (1998) and Graaff & Kolmos (2007), besides favouring knowledge construction, the PBL strategy proposes to contribute with the development of certain nontechnical skills and professional competences considered important for engineering practice in a rapidly changing society.

In PBL, the act of teaching is more than exposing information, it is to encourage the students to plan, conjecture, interpret information and, therewith, to produce forms of intervention in real problems, interacting with their colleagues, reflecting on possible actions and significant decisions.

This paper reports a workshop that uses PBL to introduce students to the concepts of electrochemistry. This workshop has been carried out with both high school students, as part of the project "UCS-PROMOPETRO: New Challenges for the Engineer of the Future" (PETROFUT) (Villas-Boas *et al.*, 2012), and students in the basic cycle of engineering programs from the Universidade de Caxias do Sul (UCS) (Sauer *et al.*, 2012). The present paper presents a section on

the theoretical framework, the formulation of the workshop, an analysis of the workshop potential elaborated in light of the PBL and final considerations.

2 Theoretical Framework

Brazilian engineering schools are reconsidering their traditional curricular structures and experimenting new pedagogical models grounded in new epistemological frameworks. These actions aim to meet the guidelines of engineering courses (DCNs from the Portuguese "Diretrizes Curriculares Nacionais"), regarding the fomentation of teaching and learning situations that enable to break with traditional teaching, promoting a new way of building knowledge in an environment that includes students having contact with real situations from their professional field. Engineers are professionals who are in constant training process. Their practice needs to meet the demands of the productive sector and society, which are constantly changing. In this regard, and according to the DCNs:

The undergraduate program in engineering has as the profile of the graduate egress/professional engineer with generalist, humanist, critical and reflective training, able to absorb and develop new technologies, stimulating their critical and creative practice in identifying and solving problems, considering its political, economic, social, environmental and cultural aspects, with ethical and humanistic vision in compliance with the demands of society (BRAZIL, 2002, p.2).

It is possible to perceive, in the DCNs, the resolution of two structuring aspects on which the new engineer academic training must be focused: the professional aspect and the humanist aspect. Regarding the first aspect, the importance of the construction of scientific, technical and technological knowledge is highlighted. As to the second aspect, the DCNs point to the need for development of citizenship. Thus, incorporating these two aspects and combining them with a critical and reflexive view, the academic training is expected to make the future graduates able to perform capably and consciously their future duties in their professional field.

One of the changes proposed by DCNs is on the curricular execution plan, which is now understood as a set of learning experiences in which the student participates actively in order to conduct studies in different areas, though in an integrated way (BRAZIL, 2002). In this perspective, we understand the need to implement new teaching and learning methodologies that include a greater involvement of the engineering student.

In this context, active learning strategies may mean a possible way to approximate the academic world to reality. More specifically, problem based learning (PBL), a strategy of active learning with great potential for engineering education, allows the selection of structuring and contextualized contents, facilitating the learning of concepts and development of important skills and attitudes in the engineer professional practice. The activities promoted in PBL are characterized as pedagogical actions, planned so that students will be motivated to participate in the learning process, integrating study groups, research practices, where they can interact with peers and teachers, sharing experiences and knowledge (Savin-Baden & Major, 2004). In the context of education, Ausubel (2003) suggests that significant learning results from a process with a set of activities in which the teacher creates conditions for the student to interact, using various materials such as challenges, problems or experiments.

Also according to Mitre and coworkers (2008), the active teaching and learning methodology, being the PBL among them, is being experimented in several pedagogical proposals from several educational institutions for the training of a professional able to develop skills of learning to learn, learning to know, learning to do, learning to live together and learning to be.

Perrenoud (2000) highlights the importance of the problem situation. This is understood as a piece of reality, a complex scenario, something that is dynamic. One of the characteristics of the problem situation is to challenge the student to act in order to overcome obstacles and conduct learning. This process is delegated to the student, authority responsible for taking on their own learning. This student becomes an apprentice for life (Barrows, 1986). To be a learner for life is a relevant skill in engineering professional fields.

In the context of learning by problem solving, Ribeiro (2005) indicates that there are different implementations of PBL, but there is a characteristic set of activities that begin with the presentation of a problem to students, who are organized in groups, trying to understand and solve it with the knowledge they already possess. Further, they highlight issues that they do not understand and plan tasks that are distributed in order to clarify them, then, they share new information with the group, integrating new knowledge and relating them to the problem. Finally, the students carry out a self-evaluation and an evaluation of their peers and of the experience.

Actions in chemistry teaching with the use of real problems can contribute to the development of different cognitive levels, of technical and transversal skills of students (Botte, 2006; Acar & Tarhan, 2007; Doymus et al., 2010; Sesen & Tarhan 2011). Teaching using contextualized problems will allow students to have a environment to develop proactive actions in their technical and scientific training. Accordingly, using PBL or one of its modalities as a strategy for a chemistry workshop enables, through its dynamics, an activity with the potential to minimize the fragmentation and isolation between different areas of knowledge that constantly permeate undergraduate programs and basic education curricula.

This paper describes a workshop involving the theme “Electrochemical and Society” that uses PBL as a teaching and learning strategy. In this workshop, groups of students developed several actions to minimize or solve the proposed problem.

3 Formulating the Workshop

On the methodological conception, the workshop offers in its dynamics the possibility of studies that supports significant learning. Characterized as a strategy of pedagogical practice - "hands-on and minds-on" – in which the space of construction and reconstruction of knowledge are the main steps for the construction of learning. This methodology foresees a space for students to question, to raise hypotheses, to test alternative solutions to the problem, to propose new actions, to argue. All these actions are favoured by the relations of the real context with the object of study and with the social group. The workshop differs from other experiences, because it has a problem as a starting point and the search for information to propose solutions. In the workshop, it is accepted various paths for the students to build their learning when trying to solve or minimize the problem, establishing interactions with people, objects and the unknown phenomenon.

The learning objectives that were established to be achieved with this workshop are the following:

- Understand which metals can react spontaneously in the environment with liquids or gases.
- Predict possible actions to minimize the effects of oxiredution in metals or alloys to avoid corrosion, economical losses and environmental impact.
- Propose real mechanisms to avoid technical pieces deterioration.

3.1 Workshop Organization

The workshop was organized in three moments, namely:

- **1st Moment (20 minutes duration) - Initial analysis of the problem by the group:** Using resources such as photos or stories (see Figures 1 to 6), problems related to corrosion of metallic materials and their impact on society were presented and analyzed with the students.



Figure 1 - Corrosion of a metal gate

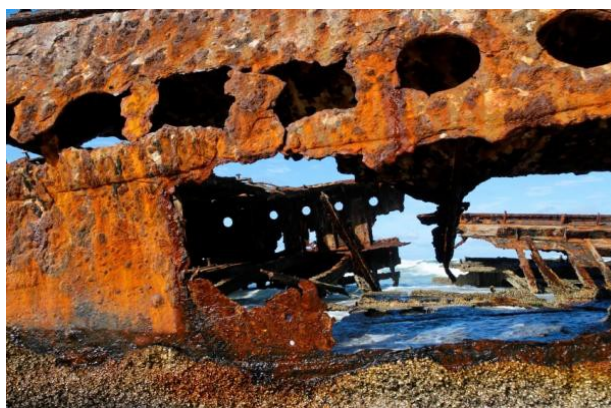


Figure 2 - Corroded remnants of a ship



Figure 3 – Example of manual electrolytic zinc coating.



Figure 4 – Final product after zinc coating.



Figure 5 – Electrolytically zinc plated screws at different stages of oxidation.



Figure 6 – A part newly chromed

At this stage students identify what they already know and do not know about the problem situation presented, formulate hypotheses and show possible interests. At this point, diversified opinions arise and this triggers the exposition of prior knowledge. The groups were formed from the questions of interest raised during the discussions. They were organized in two groups and hierarchized by the teacher-facilitator to support the understanding and the proposed intervention in the problem. The research problem selected for the study is stated below:

“Propose a viable metallic coating process to recover and recoat 200 galvanized metal parts of an automotive company”

- 2nd Moment (50 minutes duration) – Discussion systematization:** With the formulated problem and the issues raised, a proposal for action planning and readings was triggered in order to increase understanding and knowledge of structuring concepts, to intervene in the search for a solution to this problem. The main subjects of study were planned, with the guidance of the teacher- research facilitator, in increasing order of complexity. As a first step, the groups, acting as teams, sought to delimit the study, in the literature, and experiment with the resources provided to compose the likely solutions to the problem. At this stage, students discussed and identified contents they needed to study in order to establish connections to understand, analyze and act on the problem. At the workshop site chemical solutions, chemical reagents, metal materials, glassware, electrical direct current sources, wires, personal safety equipment, grippers and internet access were available to groups. In Figures 7 to 16, engineering students and high school students can be seen working in the workshop, trying to solve the problem. Mobilization for teamwork aimed to create an environment conducive to learning, exploring concepts and taking decisions in order to clarify the problem.



Figure 7 - Engineering student at the laboratory degreasing and polishing the surface of a metal part.



Figure 8 - Engineering student holding a metal ready to start the steps that precede the zinc plating.



Figure 9 - Engineering students performing the steps prior to zinc plating.



Figure 10 - Engineering students performing the zinc plating.



Figure 11 - Engineering students performing the zinc plating.



Figure 12 - Samples of zinc plated parts.



Figure 13 - High school students at the laboratory defining the stages of recovery and protection of the part



Figure 14 - High school students at the laboratory preparing a pickling acid solution.



Figure 15- High school students at the laboratory taking notes of the results of the experiment.



Figure 16 - High school students at the laboratory discussing the results obtained.

- **3rd Moment (20 minutes duration) – Solving the Problem:** The outcome of the study was the summary of all the information obtained, comparing it with formulated hypotheses and identifying new issues that necessarily required further research and other studies. The experiments were very useful in the solution of the similar situations. From the first results, discussions were triggered, aiming at understanding laws and principles, in order to prepare summaries and arguments to justify the presented solution. Each of these solutions was then submitted on seminars arranged for this purpose.

4 Analysis of potential workshop grounded in active learning

This workshop has been successfully implemented several times, with both undergraduate students of engineering courses of the University of Caxias do Sul and high school students enrolled in the PETROFUT project. In activities involving the engineering students, an evaluation of the workshop was carried out with the students who participated

in the activities. There were two open questions, about characteristics of the performance of teachers and facilitators and on the characteristics of the performance of students during the workshops.

In this paper, we present the results of 60 % of the records of the speeches of students on the two open questions. Twenty-two per cent did not answer the questions and the other 18 % answered only "liked" or "disliked".

The first open question asked the students to describe characteristics of the actions of teachers-facilitators during the workshop. Approximately 60% of the records on these characteristics are described below:

1. Teacher-facilitators characteristics:

- They are considerate;
- They do not give out answers;
- They give students hints;
- They recommend readings;
- They ask more questions instead of answering them;
- They provide new tasks when students have questions;
- Sometimes they select certain contents to facilitate students' understanding and move on;
- They praise groups for their attempts;
- They help students when they are stuck;
- They understand our difficulties, but they question everything;
- They care for the class to be a good place for work;
- They care for students' social relations;
- They help to pose questions and propose alternatives to advance;
- They support students with certain resources;
- They always take notes;
- They value students' commitment;
- They seek to formulate several alternatives to do the work;
- They let students make the decisions;
- They impose time limits;
- They make presentations with the groups and each one wants to be better than the others.

The second open question asked students to describe the characteristics of students' actions during the workshop execution. All the descriptions on students' actions during the workshops execution are listed below:

2. Students' actions characteristics:

- I was responsible for the work;
- We worked in groups;
- We made friendships;
- Communication was good to the improvement of the problem;

- There was always tasks to be done;
- There was support and space to work;
- Besides studying, presentations had to be done to other groups;
- Studies were carried out;
- Consults were carried out to solve the problem;
- Much exchange of ideas between students;
- Solving the problem felt like a gymkhana, due to time limits;
- I was worried about the execution of tasks;
- I learned from other students;
- A lot of readings;
- Contents used in applied situations;
- Selection of contents guided by the teacher.

Besides these evaluation records, we highlight the following proposals to solve the problem from groups:

3. Proposal summary from the final presentation of Group 1:

- Chemically remove the whitish shell of oxides and salts formed on the metallic base with the tested electrolytes.
- Then, follow the chosen operational sequence and finally coat the parts again using a “zinc bath”
- After the electrochemical process, store the parts in a dry place.

4. Proposal summary from the final presentation of Group 2:

- Acid pickling to solubilize the corroded area; then use organic or metallic coatings on the part to increase its resistance towards corrosion.
- Present the edification of a warehouse with good temperature and humidity control to avoid superficial corrosion on the metallic parts.
- Predict planning between parts production and supply to avoid storage.

Considering the records presented above, it seems clear that the workshop that is designed in the light of the problem-based learning offered conditions for students to develop significant learning. It was characterized as a strategy of the pedagogical practice "hands-on and minds-on" where conditions were created for the construction and reconstruction of knowledge as steps for the development of significant technical and transversal learning.

5 Final Considerations

In the applications of this workshop, it was possible to observe that some students tend to lose focus during the workshop. Therefore, constant attention of the facilitator is very important to help these students and their group to critically analyze their work and the collected material. The facilitator also needs to help the groups to focus on actions aimed at solving the problem and on the proposed educational goal. It was also noticed that several students, given their previous conceptions, tend to think that the problem has a systematic solution in some bibliographic source, or that the facilitator will give the steps to find the answer. After overcoming these perceptions, students

accept the challenge of the proposed problem and improve their decisions, studies and proposals to intervene in the problem. The solutions presented by the study groups were varied and at different levels.

One of the teacher-facilitator's challenges is to focus their efforts in student learning, in predicting conditions to ease students' interactions, keeping their self-esteem and working cognitively as a group. The experience with this strategy of active learning puts the teacher-facilitator in contact with other knowledge needs and, in this context, it is important for him/her to seek collaboration with other teachers and other institutions that have already experienced this to share the experience with this type of learning methodology. This methodology favors the improvement of educational practice, and this can only be achieved through the systematic enhancement of the pedagogical work of the teacher-facilitator. This enhancement starts from reflections on their pedagogical strategy, as well as knowledge of new theoretical bases that can support the changes in methodology with the potential for innovation in engineering education.

Finally, regarding the workshop itself, the various trials of it helped to enhance the work and, with new studies, to expand and implement the formulation of new problems in the area of electrochemistry. In this sense, when improved, the workshop can be reimplemented in other engineering courses or in high school education. Besides the construction of knowledge in electrochemistry, problem solving and overcoming obstacles give us glimpses on the students' development of technical skills and transversal skills that are significant to society and to their engineering practice field.

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DEBATE SESSIONS

Using Active Learning to attract high school students to Engineering

Use of MOOCs to attract young people to Engineering education

Elisabeth Saalman*

* Chalmers University of Technology, Gothenburg, Sweden

Email: saalman@chalmers.se

Abstract

This paper addresses Massive open online courses, MOOCs, as a new, innovative way to attract students to engineering education. It has for many years been difficulties to recruit students to engineering and science education. It is important to find new successful ways to make students sufficiently curious and interested that they choose to start studies in engineering and science education. This paper suggests the use of MOOCs as a "shop-window" to prospective students' showing the whole university and its' activities – its' education and research – providing a complete picture of what it means being a student at a certain engineering education university.

Keywords: recruitment to engineering education, MOOCs, massive open online courses, teaching, learning, active learning, physical learning environment, active learning classroom, educational technology, blended learning, web-based learning, e-learning.

1 Introduction

It is a well-known fact that it is difficult to attract young students to engineering and science education today. This is true for whole Europe and for a lot of other parts of the world. This means a really big problem because engineers are extremely important in many sectors of society and in industry and business. We need to explore and put effort on how our technical universities can show, present themselves, in an attractive and compelling way meeting young students wishes and expectations. What kind of teaching and learning approaches can we use to attract students and support their learning in a way they find both interesting and at the same time are efficient in fulfilling the learning objectives of courses and curriculum offered.

In order to meet young peoples' ways to study and learn, the use of active learning has been discussed in a lot of studies (Prince, 2004). Further the educational methods, technology and web-based course moments used need to be pedagogically well thought out to meet the students' needs for active, engaging and collaborative learning. The use of appropriate educational methods, innovative educational technology and web-based learning has been discussed in many studies (Berrett 2012; Collins, Neville and Bielaczyc, 2000; Limniou, 2010; Tolmie and Boyle, 2000).

In addition there is an increasing focus on the physical learning environment and its importance for student learning (Brooks, Fuller and Waters, 2012). The concept Active learning classroom is receiving increasing attention (University of Minnesota, 2010).

It is important that engineering education use knowledge about how students' of today prefer to study and learn, to attract (young) people to start to study at engineering education programs and to be willing to remain in the educational programs. Today there are few students with reliable Internet access who do not explore the possibility of undertaking some of their courses online. And at most universities around the world there is work going on with the aim to develop the institutional policies for online learning.

2 Background to MOOCs

The MOOC concept was established in Canada 2008 by Stephen Downes and George Siemens at the University of Manitoba, when they started the online course “Connectivism and Connective Knowledge”. To their surprise the course got more than 2200 participants (Downes, 2011).

Another striking example of a MOOC course which has received much attention is the course “Artificial Intelligence”. This MOOC was started by the Stanford University in 2011. This course got a huge amount of participants - 160 000 participants joined the course!

In 2012 Stanford University reported that more than 300 000 students enrolled for three Computer courses.

Duke University reported of almost 13 000 students enrolling for a Bioelectricity course in 2013.

An amount of 20 000 students entering a MOOC is not unusual. However there are many concerns about student completion which often stays around 10 % passing a course.

A lot of universities have followed and many of them regard MOOCs as an important way to promote themselves and offer non-profit MOOCs to students of all ages anywhere in the world. This is true for many prestigious universities, for example, Harvard University, Open University, MIT, Stanford University, University of California Irvine, University of Minnesota and several more universities.

There is no single definition for MOOCs. There are also many variations of MOOCs, for example cMOOCs and xMOOCs (Siemens, 2012):

The cMOOCs was the first MOOC introduced to the world and the idea was massive classes that were built as largely decentralized networked learning experiences. C stands for connectivist, related to connectivism. A cMOOC is characterized as a virtual, international and massive space where students and faculty share critique on each other projects. Within a cMOOC participants/learners are encouraged (but not required) to contribute actively. cMOOCs are totally open and are often seen as communities where connectivists can create knowledge together. Participants in a cMOOC set their own goals and type of engagement. The participants will probably not walk away from the course with specific knowledge of a certain content nor with specific (in advance decided) skills and competencies.

A xMOOC is characterized as a space where students are introduced to core skills. Examples are EdX platform (EdX, 2013) offered from Harvard University and Coursera platform (Coursera, 2013) including among others Stanford University. These MOOCs, these platforms, are modeled on traditional course materials and traditional teaching. They are often organized around lectures and quiz-type assessment methods and automated testing. A learning community may be present among participants or one can go alone.

The organizations EdX, Coursera and Udacity are providing xMOOCs. These organizations thus provide one interpretation of the MOOCs and typically focus on concise, targeted video content – with short videos rather than full-length lectures to wade through – and they use automated testing to check students’ understanding as they work through the content. These xMOOCs include discussion forums, and allow people to bounce ideas and discuss learning together but the centre of the course is the instructor-guided lesson.

Thus, there are many variations of MOOCs. Although there are many variants of MOOCs the starting point is a free, online, course that anyone can sign-up for and take. Some joint characteristics can be identified – openness, autonomy, diversity and interactivity (often, but not necessarily):

- A MOOC is open without no barriers to entry and no participant limit.
- Participants who join a MOOC participate in their own interests and needs and the reasons are not the same for all participants.

- No action, no activity, and no collaboration, online is required from the participants.
- A MOOC is flexible with respect to time and resources. You can as a participant enter or leave the MOOC of your own choice, whenever you prefer.
- There is no cost to participate in a MOOC.
- No application and no education criteria are needed to join a MOOC.

So, there are many variations of MOOCs and many shades of openness can be observed in various MOOCs.

Today, there are also new concepts being introduced and discussed. Some examples are Small Private Online Courses (SPOCs), Distributed Online Collaborative Courses (DOOCs) and Big Open Online Courses (BOOCs).

3 Universities using MOOCs

A lot of universities already regard MOOC's as an important way to promote themselves. Many well-known universities, for example Harvard, Open University, MIT, Stanford, University of California Irvine, University of Minnesota and several more universities have started to use MOOCs.

Harvard and MIT offer EdX courses (*EdX*, 2013) non-profit and created by Harvard and MIT which brings higher education to students of all ages anywhere in the world via the internet with free MOOCs.

University of California Irvine offers many of its' courses as open educational resources (University of California Irvine, 2013).

Another recent example is that some German universities offer open courses and ECTS credits for MOOC's by the European MOOC consortium Iversity (Iversity, 2013).

For example the University of Osnabrück and Lübeck University of Applied Sciences both offer MOOCs that provide ECTS points to the students through the European consortium Iversity (Iversity, 2013) and an examination that requires the identification, ID-control, of the student. The courses build on the concept that the students read and evaluate each other's work and other collaborative exercises.

Many universities regard MOOCs as an important way to promote themselves by using MOOCs as a "shop-window" to prospective students, to attract students and to enroll them to their university education.

Other incentives to use MOOCs are to offer open educational resources to Higher education students all over the world.

Offering MOOCs also means a way to promote lifelong learning among students/people and to meet peoples' way to study and learn.

Another incentive using MOOCs is to support student mobility.

4 Organizations using MOOCs

There are also several European organizations occupied with the possibilities of MOOC:s, and in a broader perspective blended learning, web-based learning and e-learning:

- The European commission launches a comprehensive initiative regarding open education (Opening up Education, 2013). This initiative is intended to promote digital competence, the use of open learning resources and education and access to digital resources in both schools and universities.
- There is also the European MOOC Consortium Iversity (Iversity, 2013) which offer MOOC courses and ECTS

Credits (see example above)

- UK MOOC Consortium FutureLearn & The Role of MOOCs
- European Foundation for Quality in e-learning, EFQUEL
- MOOC Quality Project
- European Association for Quality Assurance in Higher Education, ENQA.
- European University Association, EUA.
- European Association of Institutions in Higher Education, EURASHE.
- European Students Union, ESU.

Most of these organizations were engaged in a conference, an Innovative Forum, arranged by European Foundation for Quality in e-learning, EFQUEL, September 2013 (EFQUEL 2013). Representatives of the major European higher education organizations were all active contributors and willing to take part in discussions about MOOCs and e-learning in general. At this Innovative Forum a session called the MOOCathon (Marathon session on Quality and MOOCs) were arranged and a report can be found on the EFQUEL website.

Another conference “European MOOC conference 2014” will be arranged in France, by École Polytechnique Fédérale de Lausanne (EPFL) and P.A.U. Education and will be held February 10th-12th, 2014.

5 Use of MOOCs to attract students to Engineering Education

This paper suggest the use of Massive open online courses – MOOCs - as a “shop-window” to prospective engineering education students’ showing the whole university and its’ activities - its’ education and research - providing a complete picture of what it means being a student at a certain technical, engineering education university. In such a shop-window the current technical university can show the best teaching and research that the university can offer. Design and production of such a “shop-window” can give a good idea of the entire university's way to work with the most important tasks teaching, learning and research.

Such University MOOCs can in addition show the campus of the university, the university (hopefully) interactive learning environments where active learning is practiced, voices from students already studying at the university, voices from teachers and researchers etc. A content like this in a well designed and produced MOOC presents obvious possibilities to inform and attract students.

Such MOOCs could be marketed and offered to high school students, and other groups of students, to attract them to engineering education.

Some high ranked universities have invested a lot of effort and work, and also money, to produce striking, fancy courses which will attract people.

This paper thus suggests the production of interesting, striking introductory courses, MOOCs, that primarily targets young potential students, but of course also more diverse groups of potential students. The MOOCs produced need to have a well thought-out subject matter that is interesting and engaging for young students. The learning resources and tasks given to the student in the MOOC need to be real good and engaging!

Such MOOCs could be marketed and offered to high school students, and other groups of students, in order to

attract them to engineering education. In such a MOOC the potential students will have the possibility to test, to try, engineering education studies already during their High school studies.

If joining this MOOC leads to positive, tempting experiences and if the students like what they get, what they are offered this might result in more students applying to engineering universities. This may then be possible to observe as an effect on student recruitment.

6 Discussion

The use of MOOCs by engineering education universities have a possibility to reach and inform prospective students. A MOOC, a showroom to the university can be planned, designed and produced. In this showroom, promotion of the university, there are possibilities to show “rich” views of the university: the campus, learning environments, staff and teachers, the teaching statement and the pedagogy used at the university etc.

Further the subjects taught and researched at the university, future views for students and for whole world, the universities sustainability development work etc can be highlighted.

Students’ learning and collaboration in the physical learning environments – offering good interaction possibilities - of the university need to be shown. It can also be shown which competencies the students are developing during their studies at the engineering education program at the technical university. Also career opportunities after graduation are important to show to the students showing that when you have an engineering education you have wide employment opportunities in many technical/science fields in society.

The use of MOOCs have put the discussion of e-learning into focus and have, and will most probably, force also the most traditional universities to review the way they use technology and how the university and how its staff, teachers, will work with online learning in general, both on campus and on, long or short, distance. It is expected that this will influence how university teachers will be encouraged by their university management to integrate technology in teaching and learning. MOOCs can stimulate e-learning if institutions develop policies for e-learning. According to Billsberry (2013), MOOCs need to be explored: “the initial hype and hyperbole about MOOCs as a way of setting the scene for the future” needs to be explored.

Massive open learning is about developing learning in communities/networks but we need to investigate what open and massive really mean to university education.

Massive has the meaning that it should be possible for many students to participate in the MOOC. This means that the MOOC must be organized so that the participants can manage by themselves not being dependent on access to teachers. All course material and learning resources have to be available online. Thus the participants are autonomous and join the MOOC of own interest and purpose. You can regard the participation more like a cooperation than a collaboration situation.

Openness can be viewed from a number of different aspects. Open to anyone is one interpretation. Another interpretation is open in the sense that they are free, there is no cost to join the MOOC. Another interpretation is that the learning resources in the MOOC are free, can be used without restrictions from the participants and can be used and processed/reworked by the participant. There must be no obstacle either in the admission to the course or to the resources online. The MOOC is also open in the sense that you can start or leave the course whenever you like.

A general MOOC is free and voluntary which means that there is no pressure, except self-discipline, to complete your studies, and the drop-out may be high. This is of many seen as a problem.

On the other hand if a MOOC course inspires thousands of people to learn something (compare the Stanford course in 2011 which got 160 000 participants) it must still be considered worthwhile contributing to broad and lifelong learning among people. In this way a MOOC obviously can inspire people to learn more. There is no doubt that MOOCs have helped opening up learning and have given a lot of students/people access to knowledge that was previously both impossible and inconceivable. Now people all around the world have possibilities to study and learn without having to pay. The only prerequisites needed is a computer with access to Internet.

From the authors point of view MOOCs and other new concepts mentioned in this paper are not competing with regular courses; instead they are showing the benefits of education. For today's students, these forms of education are not alternatives to traditional university studies and are unlikely to be so for several years. Most universities will most probably continue with their traditional courses at campus for many years but alternatives will slowly become more appealing. The dream of replacing expensive university education with MOOCs free to the world is not realistic today.

Reasons for students to start and finish studies in higher education are about motivation, success and future possibilities to get an, interesting and well paid job. Meanwhile, during the study time the students ask for active participation in teaching and learning activities. A sense of belonging to a community and to share a purpose is important for the students' to remain in an engineering education program.

Thus, in the design of a MOOC with potential to attract students to engineering education there are several parameters we need to take into account to attract (young) students. The produced MOOC shown free on the web to prospective students for example needs to show how active learning works at the university. We need to show it, show the active learning methods, in a way that indeed attract the students to engineering education.

Two very important issues that we need to continue to discuss and debate that are:

1. How can Technology and Science Universities use MOOCs, in a strategical way, to attract students to studies in engineering and science education?
2. How can successful MOOCs be planned, designed and produced with a good and compelling content?

7 Effects on recruitment of using MOOCs

Evaluation of the effects on student recruitment to engineering education as a result of using MOOCs is an important task. It is interesting to carry out an evaluation regarding the potential of MOOCs in attracting young students to engineering education. Maybe a positive effect of using MOOCs to attract young students to an engineering education could be observed by an increased number of applicants to the engineering educational programs.

However it is not obvious how such an evaluation should be conducted to measure the effect of the MOOC. One possibility is to follow the number of applicants to engineering education. Maybe it would be possible to observe a raise in the number of students applying to the engineering education programs.

Another measure could be to ask the students in a survey about the importance of having seen the MOOC in deciding to apply to an engineering education program. Student interviews and /or student questionnaires could be offered and carried out asking questions about what in the MOOC was the most important and decisive in deciding to apply to a technical university, how the MOOC contributed to their positive view of entering to an engineering education program.

Questions like the following could be asked to the students in order to evaluate the effect of using MOOCs for recruitment purposes:

- Did you watch the MOOC about the University X?
- What in the MOOC affected you?
- What in the MOOC did you find most interesting?
- Tell about what impression you got regarding the teaching and learning approaches at the university!
- What do you think about the active learning at this university?
- What impression did you get about the learning environments?

- How did you perceive the students who already are studying at the university and who was involved in the MOOC telling about their studies and research?
- What do you think about your possibilities to get a good job after studying at this university?
- Tell what made you finally chose to apply to this university!

8 Conclusion

This paper suggests the use of MOOCs as a promising way to attract students to engineering education. The content, design and production of the MOOC needs to be put effort on in order to be well planned, produced and marketed to the prospective students.

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Using problem-based learning (PBL) in technical education

Frederico N. Leite^{*}, Humberto A. Júnior⁺, Eduardo S. Hoji^{**}, William B. Vianna⁺⁺

^{*}Federal Institute of Brasília, Campus Taguatinga, Brasília, DF, Brazil

⁺University of Brasília, Department of Electrical Engineering, School of Technology, Brasília, DF Brazil

^{**}Federal Institute of Education, Science and Technology of São Paulo, Campus Birigui, Birigui, SP, Brazil

⁺⁺Federal University of Santa Catarina, Department of Production, Florianópolis, SC, Brazil

E-mail addresses: frederico@image.unb.br, abdalla@ene.unb.br, es_hoji@ieee.org, wp_william@hotmail.com

Abstract

Problem-Based Learning (PBL) is currently one of the most applied pedagogical strategies to improve learning effectiveness, in comparison to traditional ones. This paper presents the experiences of the implementations of Problem-Based Learning (PBL) and Learning Management System (LMS) tools in a technical course, for students who finished high school, at the Federal Institute of Brasília (IFB), Brazil. A student-centered learning model using the concept of "learning by doing" was adopted, resulting in a greater students' responsibility for their knowledge. So, the structure of the subject "Communication in Computer Network", in the course of Computer Maintenance and Support, was modified according to PBL methodology. New tools and activities have been added to the subject and the interdisciplinary was improved with practical activities. Results so far indicate that the students approved this method, feeling more motivated and committed. Furthermore, they demonstrated to be more autonomous, responsible and confident in decision making process.

Keywords: Problem Based Learning (PBL); Learning Management System (LMS); IT; technical education.

1 Introduction

The lack of interest for Information Technology (IT) careers directly impacts in the labor market, limiting a country's growth. For example, it has been noticed that, in Brazil, an increasing number of job opportunities remains available due to the lack of qualified manpower, specially in the industry, which is the greatest responsible for the demand for qualified and experienced professionals (IPEA, 2007).

According to (Hojiet al, 2012), despite the immediate demand for technicians and technologists in many fields, there is a gap of 50 years in the technical education in Brazil. Because of that, an important step towards this direction has been taken with a legal framework which reorganized and regulated the formative steps within technical education in Brazil.

Moreover, the flawed basic and secondary educational systems in Brazil are unable to provide the students with all the requirements for them to think mathematically, what is reflected on their academic life in the next levels, either in technical or higher educations (Hojiet al, 2013). Furthermore, the lack of practical activities and integration with real situations during the course keep students away from the IT area.

In this paper, a teaching/learning approach based on the Problem Based Learning (PBL) and Learning Management System (LMS) tools is implemented as part of a sequenced and controlled experiment in vocational education. The PBL can bring the real problems and the learning process closer, with the possibility to reduce educational deficiencies, which are directly related to the labor market, whereas the LMS provides support for enhancing the communication between professor and students.

The proposed methodology has been applied within the subject Communication in Computer Networks (CRC – *Comunicação em Redes de Computadores*, from Portuguese), which has 120 credit hours and is part of the third and last module of the vocational course in Computer Maintenance and Support (MSI – *Manutenção e Suporte em Informática*, from Portuguese) at the Federal Institute of Brasília. The course holds a total of 1181 credit hours, from which 160 regards to the minimum required for supervised practice. Moreover, it is designed to low-income high school students, who usually come from Brazilian public secondary schools.

1.1 Motivation

The increasing number of technical schools in Brazil by means of the expansion of the Federal Network of Technological Education Institutions establishes a new scenario in professional education in Brazil. However, only few pedagogical strategies have been proposed in this educational level and a deeper reflection about the use of new teaching methodologies in the professional education must be started.

Instead of the traditional “do what I say” applied in vocational education, we believe that students in technical courses must be encouraged to think and build their own solutions for a proposed problem. Thus, considering the practical aspects of vocational education and its similarities with engineering education in IT area and the successful experiences with PBL in engineering education (Barneveld & Strobel, 2009), such method has been chosen to be applied in vocational education.

With this technique, we expect to explore interdisciplinary aspects of the course and stimulate students to build their solution within a guided procedure. Moreover, transversal skills, such as team leadership, capabilities of human resources management, good communication skills, resilience, dynamism and method and high responsibility should be developed.

2 Overview of the MSI course and the CRC subject

This research is being conducted in the last module of the MSI course, which is composed by three modules, one per semester. The course has a total of 1181 hours, including 160 hours of supervised practical activities (internship). The flowchart of the MSI course is illustrated in Figure 1.

The scope of the MSI course is providing conditions for the students to develop professional skills in IT area, meeting and acting in local demand related the support and maintenance in IT area. The target public is high school students with low incomes. Most learners who attend the course come from Brazilian public education and presents serious deficiencies regarding basic cognitive functions, what make learning a difficult task to them. It reflects the flawed basic and secondary public education in Brazil (IBGE 2013) and constitutes a challenge for educators.

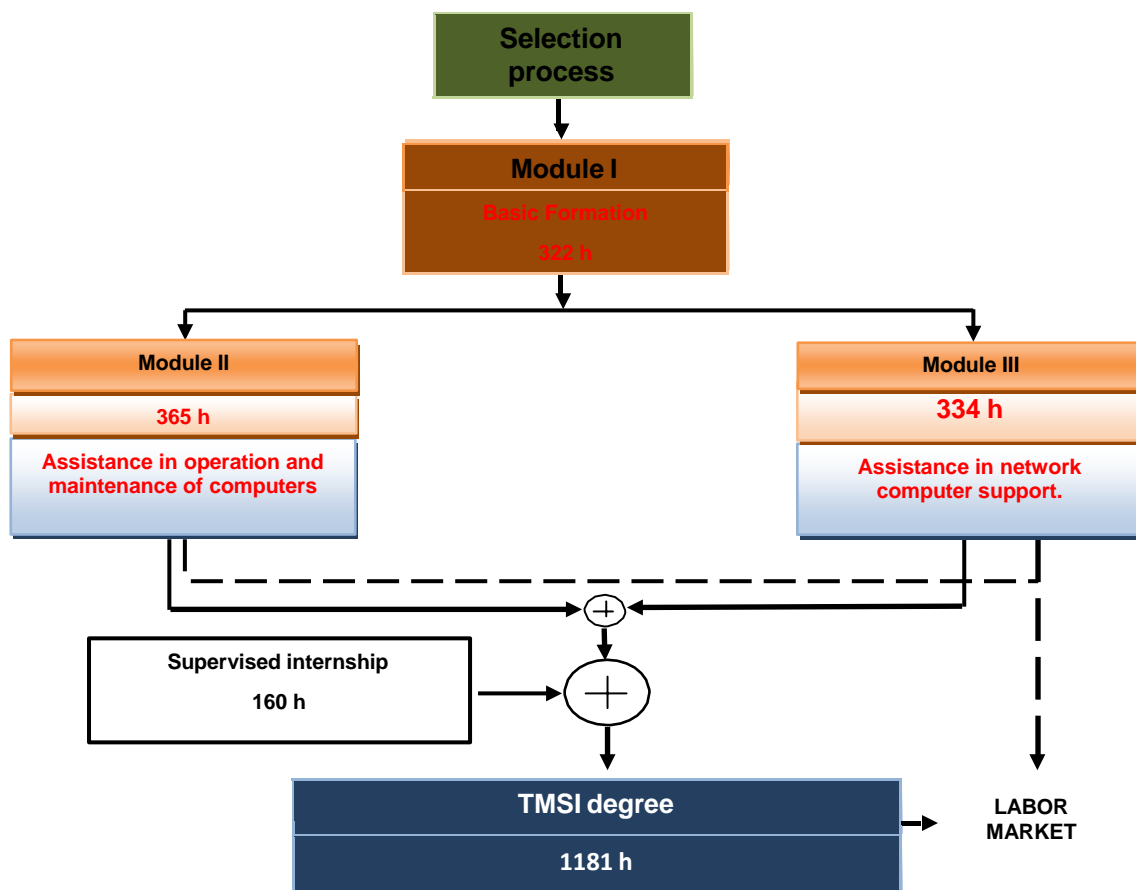


Figure1:Flowchart of the MSI course

The CRC subject is indispensable to the course and provides the students the necessary skills to develop maintenance activities in computer networks. It has a total of 120 hours, so the classes need to be interesting and motivating, or the

students will certainly be harmed, because they will not learn the main issues of the course. The subject had been taught in traditional method for five semesters in a row, and some weaknesses were verified, such as:

- The teacher was the only reference students had. So, students were completely teacher's dependent. As a result, all the problems presented to the students had to contain only the issues learned in classes and practical activities were not completed with excellence;
- Interdisciplinary aspects of the course was not explored, since there was no communication between CRC and other subjects of the course;
- The students were not motivated to solve problems proposed by the teacher, since they were only concerned with approval and not with learning;
- Most students did not understand the relationship between the subject and the labor market;
- Many students failed in the subject.

2.1 Interdisciplinary aspects on the technical course

Despising the interdisciplinary aspects of the course is very prejudicial to the students, since they can misunderstand the relationship between the subjects which composes the course and, worse, the relationship between the course contents and the labor market. For students, it is demotivating and catalyzes the truancy process.

In a brief analysis of the course structure, we found that at least five subjects are directly related with CRC, as shown in Figure 2: Operation Systems Applied to Networks (OSAN); Structured Cabling (SC); Remote Assistance to Network (RAN); Advanced Studies in Network Configuration (ASNC); Service Network Configuration (SNC).

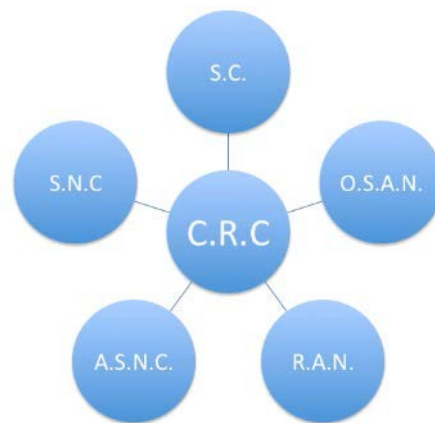


Figure 2: interdisciplinary connections with CRC in the MSI course

The issues presented on SC help the students to produce network cables required for equipment connections and organize the physical structure equipment in the rack. When the students needed to implement the network services, i.e. Domain Named Server (DNS), Hypertext Transfer Protocol (HTTP), File Transport Protocol (FTP), Dynamic Host Configuration Protocol (DHCP) and configure the physical and virtual equipment, they used other subjects. The subject that has more integration with CRC is SNC, because the students implement real equipment that they study in SNC theory.

3 Problem Based Learning (PBL) concept

Facing the problems former related, new teaching approaches were mandatory in order to allow students to be more active and to interact whereas they chase the solution for the problems. Furthermore, it had to be done based on practical activities. In this sense, active learning seems to be attractive. Such concept is applied to the learning approaches in which students are the main responsible for their learning process. According to (Bonwell&Eison,1991), they indicate that in order to learn, students must do more than listening.

Instead, they need to read, to write, to discuss, and to be engaged in solving a problem. It relates to the three learning domains referred to as knowledge, skills and attitudes, and this taxonomy of learning behaviors can be thought as "the goals of the learning process"(Bloom, 1956). However, the adoption of a methodology of teaching/learning does not involve only changes in educational and institutional processes. Instead, it requires changes in the role of the main actors: students and teacher.

Between the active learning concepts, the PBL has been utilized as a designed methodology for teaching in several area domains for over 40 years (Barneveld, 2009). It is an education methodology centered in learners, therefore we understand that the learning opportunities should be relevant to the students and that their objectives were, at least partially, determined by themselves. The students are responsible for self-learning, regardless of the teaching methodology adopted. Nobody can be forced to learn if they are not engaged in this learning process (Savin-Baden, 2007).

The learning principles that permeate the PBL models proposed by (Graaff and Kolmos, 2003) are shown in Figure 3, and comprises three approaches: cognitive learning, which is organized around problems and allows the starting point for the learning processes to be based on students' experiences, taking into consideration both the place and the context of the learning; collaborative learning, which involves the group's participants, promoting self-organization and the exchange of knowledge; and the approached subjects (contents), which are associated specially with the interdisciplinary learning, with practical examples and with the theory-practice relationship.

The delegation of authority with responsibility over the learning, prepares the students to become lifelong learners. This skill is highly helpful, especially when dealing with TIC area, because we can observe fast changes in this area in little time; thus, the professional that wants to stabilize in the labor market, should always be informed about technological novelties (Leite, 2012).

Some roles were defined among teacher and students, the learners were committed to carrying out the proposed activities as follows: exploring the problem proposed, verifying the hypotheses related to the problem, identifying and elaborating learning questions; trying to resolve the problems with their self-knowledge; establishing goals and objectives of learning; allocating resources in a way that they know what, when and how to use them; planning and delegating responsibilities for the autonomous study team; sharing the new knowledge - thus, all members of the group learn the researched issue; applying the knowledge on the problem solution; evaluating the new knowledge and using it with effectiveness and in a consistent way.

The function of the teacher is the one of a leader/facilitator on knowledge construction. The teacher needed to perform many challenging changes, such as: integrate work with other teachers, delegate authority with responsibility for the students; increase the students' motivation by applying real problems; value and encourage their previous knowledge; making an environment collaborative to learning.

Although a large number of research studies have been conducted to investigate the effectiveness of PBL introduction compared to other forms of instruction, there is no consensus on the value of PBL, but rather a heated debate on its effectiveness. Several studies corroborate that the traditional method (TM) of teaching and learning is not the best way to consolidate knowledge. For example, students involved in the passive activities inherent to TM approaches (e.g. listening and reading) retain a lower percentage of the knowledge (O'Sullivan et al, 2011).

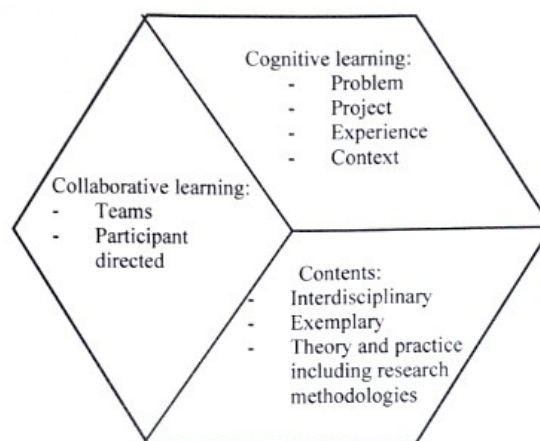


Figure 3: Learning principles of PBL

4 PBL based structure of the CRC subject

The CRC classes are generally composed by 20 students. However, it was observed that even though the number of students in each class was not high, learning evolution was slow. The students did not feel motivated to perform the proposed activities and usually the course contents were not fully presented due to the great difficulty that the group had to assimilate what was being taught. Therefore, the subject was restructured, amplifying the scope of the

proposed activities, trying to bring the labor market's reality into the classes' activities and to explore transversal abilities, such as leadership, group work and self-confidence.

In this research, we consider the student-centered learning approach. For example, the students enrolled in CRC are responsible for resolving the challenge work proposed by the teacher. To do this, they do not solve the theoretical issues, but they need to build their own chain of knowledge with their experiences and necessary skills for resolution of the problems. Also, LMS tools were considered to enhance the communication between students and professor.

Another important aspect of IT courses regards to network simulation, which is commonly used in computer network research. It is a technique where a program simulates the behavior of a network by calculating the interaction between the different network entities using algorithms and technical observations for a network production. The behavior of the network and the various applications and services it supports can then be observed in a test lab and various attributes of the environment can also be modified in a controlled manner to assess how the network would behave under different conditions. Network management systems are the most important elements of a successfully functioning computer network.

The maintenance and configuration of network devices, servers and services, as well as continuous monitoring of the operation of all the devices within the network, are the key elements of a network management system. In order to ensure the reliable management of devices and services, it is necessary to design a network in such a manner that it provides the highest level of security isolation of management traffic from production traffic. Another aspect of the successful management of computer networks concerns the network protocols used for this purpose, as well as their implementation, i.e., the manner in which they are used.

The network simulation is very important for this research, because before the learners configure the real equipment, they need to learn how to configure a virtual network. Thus, we minimize the probability that the student paralyzes the network that is in production, i.e., when students demonstrate enough knowledge based on the network simulation, they are able to implement all the proposed simulations in physical equipment.

Therefore, in PBL context, we were proposed that the subject was divided into phases, as shown in Figure 4. Each phase contains a group of activities and abilities that should be explored by the students and at the end of each phase, new learning verifications (VA) are carried out. If a student fails in a phase, the teacher/tutor highlights his/her specific difficulties and conducts him/her to teaching assistants, who provide the student with personalized assistance. The blue arrow means that in any phase and any time the students can consult the teaching assistant or tutor.

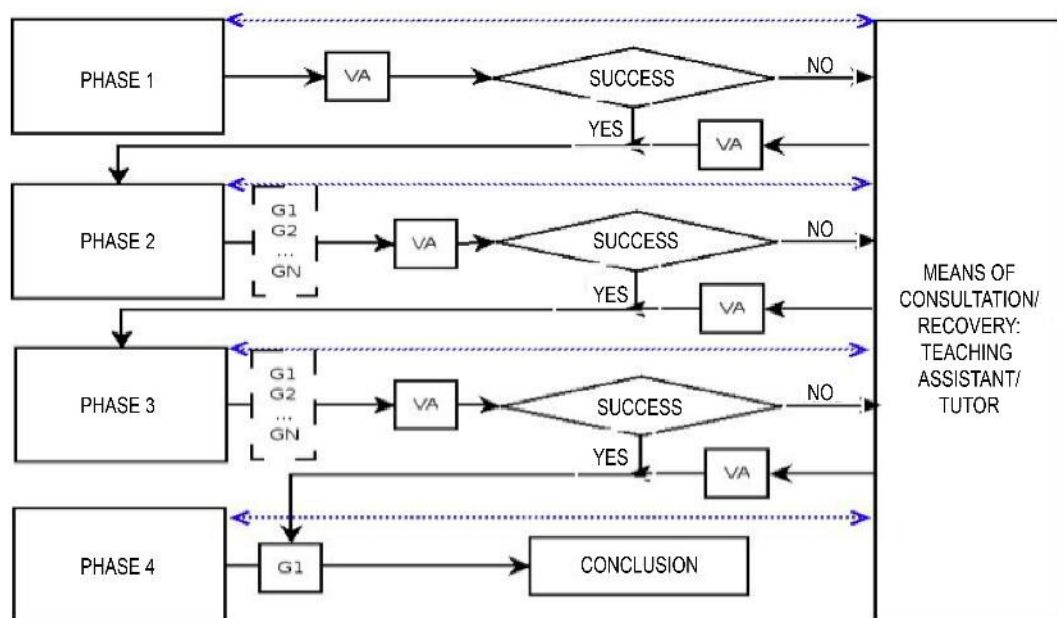


Figure 4: Activities flowchart.

From the second phase on, the class is divided into small groups of about 3 students. One of the students is elected to be the leader, who is responsible for the learning of the other members of the group. In phase 1, the subject is related to the bibliography; in phases 2 and 3, it is related to practice; and in phase 4, the class gets back together in one group (G1), to develop an activity that requires systemic thought and the application of interdisciplinary knowledge.

At the end of the course, the students will develop a scientific article and educational videos that present the execution of the activities performed by the groups. They will use the LMS tools to share information, communicate with the teacher and with the teaching assistant, to publish didactic contents, present solutions for problems common to all groups and develop e-learning activities proposed by the teacher.

The time for phases was dimensioned according to complexity of each step; it can be seen in Figure 5. On the phase 1, twelve hours were reserved for a review - considering that the subjects of network computing were necessary for the students to perform the proposed activities - and it was taught on the first semester in the course. Therefore, most students had difficulty to remember the basic network concepts. At this phase the teacher sets the activities that should be performed on the course and the students should present, as an output (evaluation), a simply network project that involves the communication of a company (headquarter) and their branch. They should show the equipment necessary to configure it and set the network services they will use. For example: Domain Named Server (DNS), File Transport Protocol (FTP), Voice Over IP (VOIP).

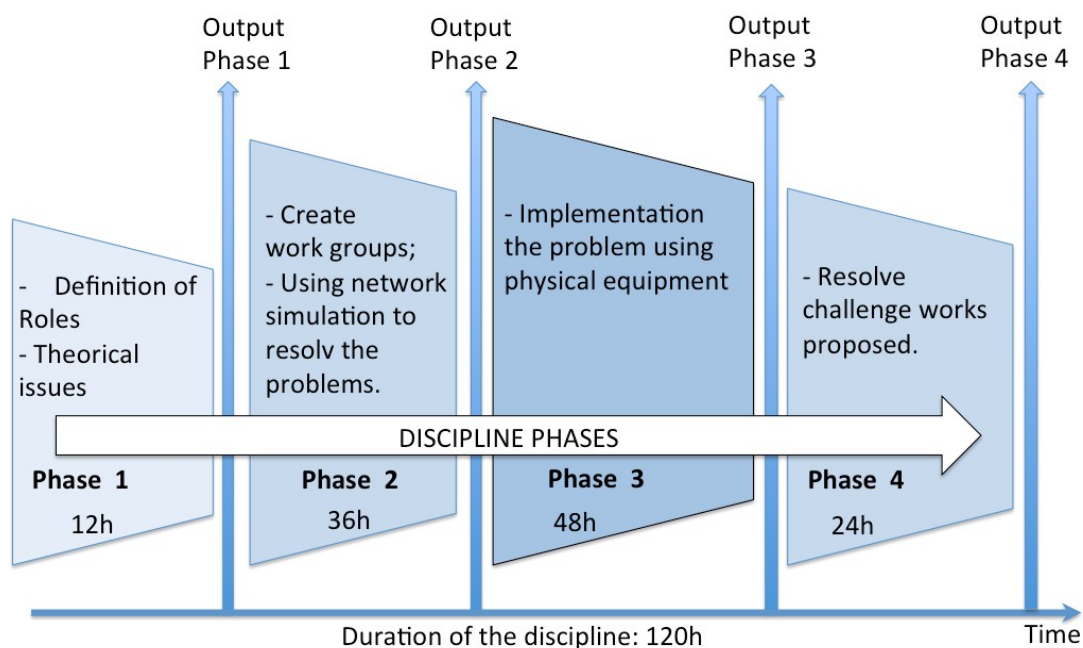


Figure 5: Duration and expected results of each phase.

On phase 2, thirty-six hours were reserved. This step is more complex if it is compared to phase 1. The student would implement in network simulation; for example "Packet Tracer", the output proposed project in phase 1, including some other services provided in subject like EACR and CSR. The created groups should present, as an output of this phase, the proposed challenge network simulation.

On phase 3, the activities were directed to the physical equipment configuration available on laboratory. The students should solve real problems found in the labor market. Therefore, forty-eight hours were reserved, because they needed to feel safe in real problem solution. At the end of this step, the groups should write a scientific article as an output of this phase. They also should record a video explaining and showing their performance of the activities and it should be presented to the class.

On the last phase, the group (G1) is responsible for dividing tasks and organizing the activities in physical equipment. The teacher proposes a great task, and the students need resolve this problem. The students have the opportunity of applying what they have learned in theory. As the output of phase 4, they need to implement and present the solution of the activity proposed by the teacher. Twenty-four hours were reserved for this phase. We named "challenging activities" because the students had never performed a real network service implementation before and they had not integrated it with real network equipment configuration.

4.1 Learning Management System (LMS) as a support tool

The LMS is the means by which course information is distributed to students. It is common for an institution to periodically review its LMS system (in our case, the Moodle). For many institutions, the LMS is the most significant enterprise system for teaching and learning. However, at IFB it is not the reality; it does not prioritize this type tool, only a small number of teachers adopt the virtual environment in their discipline. This is unfortunate, however,

because according to (Kim & Lee, 2008), the tools available in the LMS help in learning and bring benefits to the educational development of the student.

The Moodle is capable of fulfilling most of our discipline related requirements and it used to develop and share learning materials. It also supports collaboration via forum, wiki, squeeze, chat, etc. We also tried generic solutions for enhancement in an e-learning collaborative environment, in face-to-face course.

5 Activities developed and methodology screening

In phase 1, the subject CRC was led as a traditional learning method: the teacher was an expert or formal authority, transmitting information. He organized the issues as if it were a lecture. The activity on this phase is related to a brief review of the basic essential concepts, in order to develop the subject. However, in this phase the students are not only viewers, but they plan the next phases and create work groups. Also, a first practical activity was performed in this phase. In order to better assimilate the theoretical concepts presented at this phase, students were encouraged to simulate a network behavior.

In phase 2, the groups began to be organized, the monitors accompanied the activities. In this phase, students should start to solve practical problems, but it was clear their resistance to accept the new method. They kept waiting for the solution of the problem, instead of acquiring their own knowledge and building the solution when an activity was proposed. So, the students were forced to build their solution and in a little time they felt confident and, consequently, more motivated. The new learning methodology was being effective, since activities that could not be implemented before, were now a reality. The preliminary results exceeded initial expectations. The students did not care only the grades, but they were also concerned about learning the subject. As a consequence, a simple physical equipment configuration had to be performed in answer to the students' anxiety to integrate theory and practice.

In phase 3, the possibility of the students implementing the theoretical issues in practice helped them feel more motivated. The first contact of the students with physical equipment was highly positive. They verified that this subject would be able to help them in the labor market. However, the development of the scientific article needed the teacher's help due to the students' lack of experience and ignorance regarding scientific methodology rules. After some reviews, the results were satisfactory. At the end of this phase, some students wished to include in their class work activities envisaged on phase 4.

The class was divided in four groups, in which students had to do the activities that involved the interdisciplinary of the course, as it is shown in Figure 2. Each group needed to perform an activity in common and implement a network structure, but with specific issues: Virtual Private Network (VPN); Voice Over Internet Protocol (VOIP); and Multi-Protocol Label Switching (MPLS), Virtual Router Redundancy Protocol (VRRP). At the end of the activities, one of the groups could not complete the work, because they had much difficulty to understand the proposed issue, but they presented the problems they found and suggested a solution for them. They could not resolve them, because they did not have more time to correct.

In phase 4, the students' work was even more challenging, because it involved a lot of knowledge from other disciplines and issues that had never been worked before in the course. Therefore, this phase is not mandatory, i.e., it did not influence on students' grade, but for the teacher's surprise, all students involved in the discipline wished to work with this activity.

The learners had many pieces of equipment available to configure: four routers, four switches, two firewalls, and two server machines with the operational system Debian working. The laboratory and the equipment can be seen in Figure 6.



Figure 6: laboratory and equipment.

In the proposed activity, the students should integrate the equipment of the institutional laboratory with the equipment they would use to configure; they needed to install and to configure network services; to configure VLAN; and to implement a routing algorithm, such as the Open Path First (OSPF) and the Routing Information Protocol (RIP). To elucidate the activities that the students needed to perform, an illustration of the structure set up by the students is shown in Figure 7. We divided the areas in laboratory: in area 1, the hosts were connected through internal IFB network; thus, the students needed to integrate it with equipment that they would configure (area 3); the machines in area 4 did not have network services installed, so, they should to install and to configure these services: DNS, HTTP and FTP. In area 2, 5 and 1 the hosts needed to communicate with area 3, i.e., the students should to configure and integrate all presented areas.

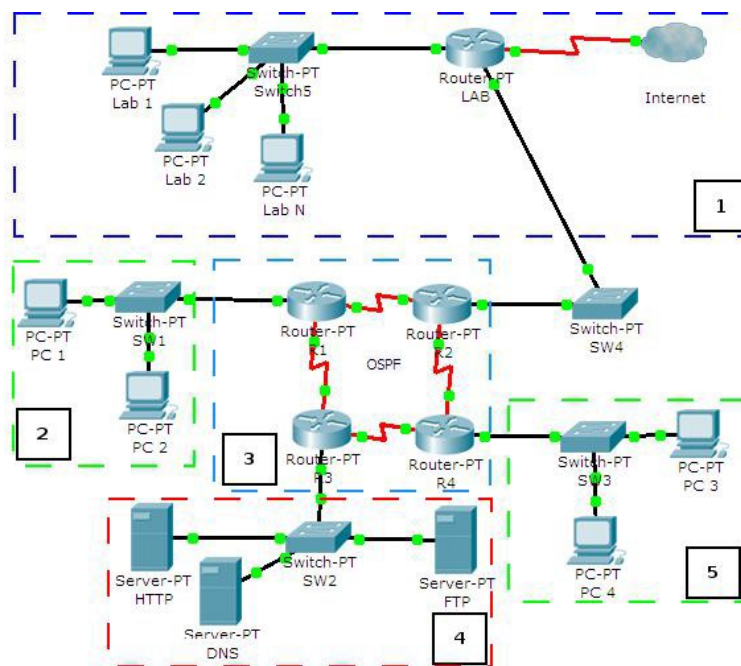


Figure 7: Structure of the network that was configured by students.

The methodology used in phase 4 was defined by the students. They organized and divided the work by themselves. The group (G1) elected a leader and he was responsible for dividing and guiding the proposed activities. All activities on this step were completed, and the learners reached their goals.

Regarding the use of LMS tools, students naturally replaced many resources such as forum, wiki and chat by other daily used tools, e.g. Google Drive and Facebook.

5.1 Students' feedback

This study began in the first semester of 2013, with a group of 16 students. The efficiency of the proposed method was validated through a qualitative research method based on the techniques from (Bardin, 2006). Data collection was carried out through interviews with assistants and a questionnaire composed by 16 objective questions and an essay question in which students were encouraged to suggest, criticize or commend the methodology. So, it was possible to validate the proposal in the following dimensions: the PBL methodology; the efficiency of the LMS tools; and the subject in general.

Fourteen students completed the questionnaire and the interview was conducted with the 2 assistants. Collected data indicate that the students approved the teaching/learning approach, since they felt more confident during decision making processes. Also, they considered the LMS tools helpful in the learning process.

The answers to the objective questions can be seen in Table 1. The numbers in the table indicate how many students chose each answer.

Table 1: Questionnaire for the students' feedback.

Questions	Do not understand	Totally disagree	Neither agree nor disagree	Somewhat agree	Totally agree
In your perception, do you think that this subject was helpful to the TMSI course?				3	10
I felt motivated to perform the teacher's proposed activities				7	7
The challenge of the final project - on phase 4 - made me feel more confident in solving unknown problems			2	7	5
The monitors' participation was helpful in the subject activities			2	5	7
The use of network simulation was useful in practical activities			3	3	8
The PBL was useful to develop the laboratory activities				7	7
In comparison to the traditional learning method, the PBL facilitated the learning process			3	10	1
The PBL methodology can be helpful in my professional performance			1	3	10
On-line materials were useful for my performance in the subject			3	8	3
Students' lectures were useful for the learning process				10	3
Equipment guides were useful for practical activities				3	10
The LMS tools, such as chat, forums, blog, and wiki were useful for the learning process			2	10	2
I enjoyed the new teaching method				5	8

Besides the objective questions, the students completed a descriptive field destined to suggestions, criticism or compliments. We applied the qualitative analysis in the data collected and emerged some categories, themes and verbalization. The main categories are shown in Table 2:

Table 2: results of the qualitative method.

Categorization	Theme	Verbalization
"The PBL Methodology consumes a lot of time."	Complex Activities.	"The PBL method is good, but it consumes a lot of time"; "We needed to study hard in order to develop the activities"; "we should study for CRC, but we needed to study for other subjects, and it was not easy."
	Difficulties in meeting with the groups.	"I need to work and study, so, meeting with the groups was not easy"; "I am learning a lot, the new method is interesting, but I spent much time for meeting groups".
"Learning with PBL"	Motivation	"The method "learning by doing" helped to establish the knowledge more efficiently"; "In little time I was involved with the teacher's proposed activities"

"The teacher had experience and knewhow to conduct the subject"	Results of the method	"Initially, I thought that the teacher did not want to work, because he did not teach the issues and charged results, but after sometime I realized that with the new learning methodology I can learn more."; "The teacher has a lot of experience, knewhow to conduct the subject and guide the work groups. Congratulations to the teacher"
"Support of LMS tools"	Moodle	"The use of the Moodle was important for integration between the teacher and work groups", "I did not Knowhow to use the Moodle, but in little time I learned it, but now I like so much to use it, because the Moodle's tools are easy".

The monitors' work was fundamental to develop the subject, many students sought the monitors in order to clarify doubts; they helped the teacher to organize the laboratory activities; and produced an educational video to guide the students to implement the network services presented on phase 4. The monitors were also interviewed, and they said they needed to work hard to develop their activities, but as they were learning a lot with proposed work, they were motivated.

In addition to the better management of the subject contents, which helped to increase the students' motivation and interest, students' performance has also been improved within the PBL environment, as it can be seen in Table 3. The average students' grades were higher than the former class', which had 14 students and the learning was based on the traditional method. Also, the number of students who dropped out or failed in the course were reduced. The minimum grade required to student's approval is 6.0.

Table 3. Comparison classes.

COMPARED ISSUES	CLASS YEAR	
	2012/2 (TM)	2013/1 (PBL)
Class' average grades	4.9	7.5
Students' dropped out	4	2
Students' failures in the subject	3	1

6 Conclusions

The results so far indicate that the methodology proposed provide the students a framework concerned with practical activities within they are encouraged to build the solutions for their problems, instead of just "accomplish regular maintenance routines". After an initial resistance to the new method, students joined the PBL activities and demonstrated to be more confident and enthusiastic during decision making processes within this methodology.

However, few adjustments are necessary and some of them were carried out during the semester with the development of some additional or non-programmed activities in practically every phase. It is important to say that part of such activities had to be done as the answer to students' anxiety for practical activities with the equipment available in the lab.

Some difficulties found by the students in the use of the LMS tools, led to their replacement for popular tools, such as social networks and Google tools. They seem to be more attractive to the students due to their ability with such tools and, therefore, they might be considered to provide the necessary communication support between students and with the teacher.

This research is ongoing with the currently enrolled class, which started at the second semester of 2013.

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Students' Perceptions of Skills Importance to Engineering

Adriana A. Depieri*, Roseli D. Lopes*

* Departamento de Engenharia de Sistemas Eletrônicos, Escola Politécnica, Universidade de São Paulo, São Paulo, SP, Brazil

*Departamento de Engenharia de Sistemas Eletrônicos e Centro Interdisciplinar em Tecnologias Interativas, Escola Politécnica, Universidade de São Paulo, São Paulo, Brazil

Email: adrianadepieri@usp.br; roseli@lsi.usp.br

Abstract

With the market for engineering talent heating up in Brazil, encouraging young people to pursue a career in Engineering is crucial in building a strong foundation for a successful future nation with highly skilled engineering workforce. Since high school education is a starting point in determining young professional futures, students need to be aware of what it takes to become successful in the field of engineering. To verify if students have misconceptions regarding the importance of some hard and soft skills to the field of engineering, a survey was conducted with 508 high school students. Despite mathematics is considered by students the most important skill to succeed in engineering, survey results also demonstrated they do recognize the importance of other skills to prosper in engineering.

Keywords: skills, engineering skills, engineering education, active learning.

1 Introduction

Brazilian engineering education has faced a double challenge: to educate citizens to live within a rapidly changing world and to train professionals to meet the broad spectrum of demand and changing labor market. It is as a systemic condition essential to improve the competitiveness of the national economy and to facilitate the evolution of society (Rocha, 1996). Furthermore, a full generation has been living abs learning online, yet participation in formal education is still largely accomplished face-to-face in physical space. The big challenge in Brazil, and also worldwide, is to help people think about and navigate this transformation in the light of the global knowledge-based economy, where more and more emphasis is placed on how to form future skilled professionals, especially engineers.

The existence of an educated population, with appropriate levels of professional qualification, able to adjust to permanent technological turnovers, is a necessary condition for the development of a country, for its own competitiveness and the quality of life of its citizens. One of the biggest challenges for Brazil in the 21st century is to achieve satisfactory standards of education and professional qualification. And in tackling this challenge Brazil can count on more than half a million masters degrees and about 190,000 doctoral degrees. However, satisfactory standards of education and professional qualification depend not only on graduates quantitative importance, but also its quality, diversity and its actual conditions of employment.

It is not easy to form and train professionals to meet the challenges encountered in this new century, but in response to this challenge, a considerable transformation of high school and higher education ought to occur in order to promote more effective learning at all levels. And due to Brazil's economic growth closely linked to the increased demand for engineering professionals, there is a continuous demand of skilled professionals growing parallel to the growth of it's economy. In addition, the professional skillset of the engineer is required not only in the country's own activity engineering, but also in many other activities that require the nature of the knowledge developed in the training and professional performance engineer. Therefore, encouraging high school students to pursue a career in Engineering is crucial in building a strong foundation for a successful future nation.

In order to use skills knowledge to support student learning and to analyze specific skills that could make engineering pathway easier, it is important to consider what high school students know about the role skills play or represent to engineering. Therefore, the purpose of this study was to determine high school students' perceptions on how important soft and technical skills are to engineering.

Contextualizing this study in a global engineering scenario, the first section of this paper presents some compared numbers of Brazilian engineering and education. Section two describes the importance of high school and its skills in determining young professional futures. Then it presents new engineering skills required for a changing world, before detailing our study on high school students' perceptions of how important some skills are to succeed in field of engineering, and how these perceptions relate to their identification characteristics in section four. Finally this paper describes and analyzes the collected data, ending with discussions and conclusions.

2 Some Brazilian Engineering and Education Numbers

Brazilian Federal Council of Engineering, Architecture and Agronomy (Confea) and Regional Councils of Engineering and Architecture (CREA), have registered around 780,000 professionals in the last ten years out of approximately a million in total. But despite the last decade's increase in the number of engineering opportunities for engineering degrees and enrollments in all regions of the country (with a 12% average growth per year between 2001 and 2011), only 5% of Brazil's undergraduates major in engineering compared with 6% in the U.S., 12% in Europe, 20% in Singapore, and 40% in China (IEDI, 2010; Telles, 2009). In Brazil, the number of undergraduates that majored in engineering is 26,000 thousand per year. In China, 450.000 engineers enter the market annually while this number in India is 200,000 and 80,000 in South Korea (Telles, 2009). Although there is an actual Brazilian favorable engineering scenario, figure 1 shows Brazil's position in an OCED international comparison of undergraduate engineering numbers per 10,000 inhabitants in 2007, in which Brazil is far beyond more developed countries (Salerno et al, 2013).

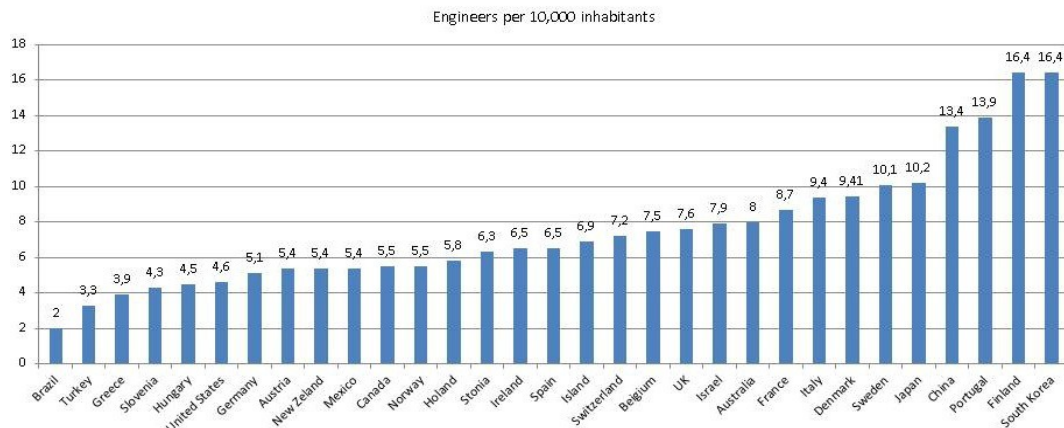


Figure 1: Number of undergraduate engineers per 10,000 inhabitants in OCDE countries in 2007 (Adapted SALERNO et al., 2013)

In terms of graduate education, the country has experienced remarkable growth, and has greatly expanded its areas of research. The number of masters' degrees and PhDs graduated by Brazilian universities has more than quadrupled in 15 years, jumping from 13,219 in 1996 to 55,047 in 2011. In 1996, 10,389 were awarded master's degrees and 2,830 doctoral degrees, while in 2011, the number of masters and doctoral degrees obtained had grown respectively 312.26% and 331.70%, with 42,830 new masters and 12,217 new doctoral degrees in 2011 (CGEE, 2012), considering all areas.

In 2010, from the total of graduate degrees obtained, 11,300 doctoral and 39,600 masters' degrees only approximately 10% and 5% respectively were in the area of engineering. Figure 2 shows the evolution of doctoral and master's degrees in engineering from 2001 to 2011. Nevertheless, this growth was not enough to place the country among countries with large engineering research, as from 2001 to 2005, Brazil contributed with only 1,4% of world engineering research against United States' 28,1%'s, Japan's 10,3% and China's (Telles, 2009).

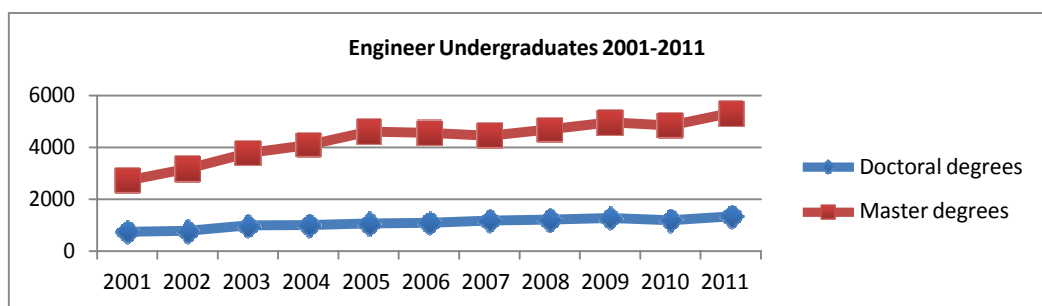


Figure 2: Numbers of obtained Brazilian doctoral and master's degrees evolution in Engineering from 2001 to 2011. (MCTI, 2012)

In spite of the greater number of opportunities for engineering degrees, enrollments and undergraduates lately, the country needs to form "more and better engineers" in order to climb new heights, not only technological, but also in terms of economic, social and political development. According to Tozi & Tozi (2012), engineering undergraduates, undergoing a curriculum with a strong mathematical and logical content-oriented problem solving, are very well prepared in the sense of "learning to learn". This is the essence of not only active learning, but the essence of future education in order to provide the development of new required professional competencies for a new era global

market. But in order to increase the number of engineering undergraduates and graduates, it is important to encourage and motivate more adolescent learners to pursue careers in engineering and to raise interest in STEM education.

Inspiring students to enter the engineering profession remains a high priority concern among governmental agencies and professional societies. Even though the number of Brazilian citizens pursuing science and engineering degrees, primarily undergraduate and doctoral, has increased for the past ten years, students' capability in science and mathematics seem to not show significant progress towards high school graduation, as demonstrated by PISA (Program for International Student Assessment) results (OECD, 2009). In spite of the well-known relevance of science and mathematics for the creation of engineers, this mismatch of basic educational needs may be discouraging students from the engineering profession and making them choose a different career path.

Due to Brazilian bad results in PISA (Program for International Student Assessment), there is also an urgent need for initiatives to strengthen and improve mathematics and science teaching in the levels of primary and secondary education (Telles, 2009). Coordinated by the Organization for Economic Cooperation and Development (OECD), the PISA assessment measures 15-year-old students' reading, mathematics, and science literacy, besides measures of general or cross-curricular competencies, such as problem solving. PISA emphasizes functional skills that students have acquired as they near the end of compulsory schooling. In 2009, Australia had 38.1% of students in level four or higher on the PISA 2009 mathematics assessment, Canada, 43.3%, South Korea, 51.8%, China 71.2%, while Brazil had only 3.8% (OECD, 2009). According to the OECD website, PISA 2012 focuses on mathematics literacy and also assesses reading and science literacy. PISA 2012 also includes computer-based assessments in mathematics literacy, reading literacy, and general problem solving, and an assessment of students' financial literacy, but its results were not released yet.

By creating a mixture of different learning opportunities, it is possible to help students encounter new information, develop skills, try out ideas, and build knowledge (UNICEF, 1999). But the low quality of high school education may affect youth desire to pursue engineering education, especially because theoretical classes with little laboratory experiments may interfere in the lack of interest of young people in engineering. Another thing to be considered is the lack of knowledge about an engineering career that may make young people opt for other careers. However, active learning methods can be more explored and used to develop and strengthen students' learning and their development of required engineering competences, in order to help attract young people to engineering careers. Active learning instructional strategies include a wide range of activities that share the common element of involving students in doing things and thinking about the things they are doing (Bonwell & Eison 1991). Academic practices inclined towards more cognitive development, giving rise to programs of studies and experiments by improving the quality of high school education and enhancing the whole high school education process may be a path to meet global future professionals' requirements, especially engineer ones.

The Brazilian National Curriculum Guidelines for high school education has established that the curricula must be designed based on competences and skills rather than on the content. Although it leaves no clear concept of competence nor skills, it may be emphasized that "competence" is still "a concept under construction", due to the difficulty and to the many approaches to define and interpret this phenomenon (Nakao et al, 2012). And a good definition of "skill" may be the ability with reference to the task needing to be performed, and the level of competence required (UKCES, 2009). Skill is, therefore, the ability to perform a task at the required level of competence, while "competence" relates to the possession of required skill, knowledge, qualification, or capacity (<http://dictionary.reference.com>). But trying to simplify these concepts, Nakao et al (2012) stated that competence is the combination of the knowledge, skills and attitudes by proposing a definition of competence in the form of an equation relating each of these elements and giving their relative importance:

$$\text{Competence} = (\text{knowledge} + \text{skills})^{\text{attitude}}.$$

A reflection on the elements of this formula reinforces the need for knowledge and skills, but also indicates the great influence of attitudes on competence. The competences should be exercised in a setting, in a specific context, in a certain environment, in a function or position, seeking for results and being efficient.

Besides the difficulties in having an international agreement on appropriate translations, and the difficulties in understanding and differentiating the real meanings of competence, knowledge, skill, attitude, and many other related words, it is clear that the new profile of the Brazilian engineer needs to combine not only technical (hard skills) but also transferable (soft) skills.

3 High School Education and Engineering Skills

The changes students will face as they make the transition from high school to college academics, not only physical and emotional changes but also all new challenges that will go through, are inevitable and it takes time to get used to it. While high schoolers may not be able to wrap their heads around the idea of professors instead of teachers or lecture halls filled with hundreds of students, they can begin adapting to the necessary study methods before making their career choice.

High school education is supposed to prepare students for college. Besides teaching students how to learn on their own, students also need to learn the so-called “21st century skills” such as problem solving, critical thinking, and media literacy to prepare for the new global, digital economy (Stanbury, 2011). Business and industry continue to suggest dissatisfaction with the lack of academic preparedness by some recent graduates and/or employees due to the importance of these soft skills (Mackenzie, 2004; Alsop, 2004). These kinds of assessments provide data that can be used to modify the curricula and teaching techniques considered necessary to prepare future professionals with skills necessary for the 21st century workplace.

As with most careers these days, students need to start planning in high school to ensure they take the right kind of subjects which will enable them to pursue engineering later at university. But more than that, students need to know why subjects and skills are important, and identify some study strategies in high school which can pave the path to success in university academics.

According to Han (2011), professionalism, work attitude, self-management skills, people skills, and hard skills are five building blocks to success in any career. And out of these five components, soft skills represent two (self-management skills and people skills) of these building blocks and are the most important to career success (Han, 2011). So for this paper we classified skills in three categories or three building blocks that would be more appropriate to high school students level, which served as the basis for our survey.

- High school hard skills (high school knowledge) – native language skills, arts, math, chemistry, physics, biology, geography, history, philosophy, sociology, foreign languages (English and Spanish), ecology / environmental sciences, multidisciplinary knowledge, lab work.
- Technical Skills – how to use computers, programming, data analysis, experimental work, management and business techniques, technical drawings/design, electronics, robotics, etc.
- Interpersonal & personal skills – group and individual work/studies, reading habits, hands-on abilities, curiosity, creativity, initiative, investigative spirit, persistency, social abilities, leadership, critical thinking, problem-solving skills, math reasoning, communication skills, interpersonal skills, work ethic, attitude/disposition, organizational/time management, and leadership skills, Entrepreneurship, Decision taking, Invention/Innovation, Activities management, Problems identifications, formulations and solutions, Meet schedules, deadlines and targets, Spatial sense, Applying Math, scientific and technological tools (Han, 2011).

High school subjects and activities should directly or indirectly help students to strengthen and develop skills, which will help them achieve success not only in school, but in their chosen career and life. In addition to studying math and sciences, the study of many other subjects will help students to develop transferable skills that will help them to become, and be, better engineers. For example, engineers need to have well developed communication, teamwork and project management skills. Students will only develop these kinds of skills by trying new things and taking a broad range of subjects in school.

Communication skills are also critical to succeed in any career. Students need to continually develop and improve their reading, writing and speaking skills. Subjects which can help students to improve communication skills include native languages skills (Portuguese in Brazil's case), literature, speech/communications; debating, media relations, journalism/broadcasting. Taking a foreign language subject (English and Spanish taught in Brazilian schools) can also be an advantage by learning about the language, culture and customs of another country that can be a valuable job skill as the world is a global economy these days, and many engineers live and work overseas.

Students' experiences in high school are expected to influence their actions and experiences in university (Bogaard, 2012). As any other area, engineering technical acumen alone is no longer sufficient for engineering career success, and soft skills have played an important role in differentiating STEM (Science, Technology, Engineering and Mathematics) professionals for employment and advancement (Riemer, 2003). Active learning empowers students with soft skills, giving them the needed tools to be able to effectively apply and make use of their knowledge for a successful career choice and lifework. When students learn to apply the technical content learned from texts and real

simulations, to integrate material across various areas, they take active responsibility for their learning, as agents of the process of building up their knowledge by learning by doing (Villas-Boas & Martins, 2012).

Even knowing that most of engineering schools focuses on developing technical skills of their students, the development of organizational and behavioral skills are more and more highly valued by the labor market. However, the goal of most teachers in engineering schools is to assist the undergraduate student in the development of requirements for understanding the concepts and practice of Engineering.

Required engineering skills for lifelong career success is well-established in the literature (ABET, 1997; Maddocks et al, 2002; Krishnan & Davis, 2012). However, pre-engineering high school required skills in order to enhance success during engineering graduation courses seem to be not a worldwide consensus. We believe there is a need of stressing it and also making it more clear to high school students how important certain skills are to the engineering career. The knowledge of the importance of skills necessary to engineering may be a path to help attracting not only in numbers but in better skilled students to enter university engineering levels. Therefore, it is better to make sure that they have the needed skills Instead of wondering whether high school students will be successful in engineering.

4 Materials and Method

To address the question of how important skills are to succeed in the engineering field among high school students, a quantitative method was used to perform a content analysis based on students' perceptions through their survey answers in a hardcopy version.

4.1 Pre-tests

A first pre-test student survey was developed, based in well-established literature (Hilpert et al, 2008; Hirsch et al. 2003; Ball et al 2012; Meyers et al 2012; Robinson & Kenny, 2003; Molina-Gaudo et al, 2010). Two high school students (one 16 year old male and one 15 year old female) took the pre-test while, notes were taken of their comments and complaints. The 35 to 40 minutes spent time to answer all the questions was considered too long for a survey like this. Therefore, adjustments were done to the first pre-test survey.

Items (survey questions) were grouped and placed into a matrix in order to balance the number of items referring to each kind of assessment. Before the second pre-testing, some more adjustment were done, the matrix was reevaluated and items were reduced in numbers before proceeding to the second pre-test. A few days before the event where data would be collected, 5 high school students (4 female and 1 male) completed the second pre-test, and the time they took to respond was around twenty minutes.

4.2 The Survey

A student survey was developed in order to determine to what extent, if any, high school students' perceptions of differ when correlated to their personal characteristics. The survey assessed the students' overall perception on the importance of some skills needed for succeeding in the field of engineering through close ended questions, but for this paper .

The survey structure for this research consisted of two parts: participants' profile and evaluation questions. The profile section provided information on age, gender (female or male), type of school (public, private or both), kind of high school attended (regular, technical, both and others) and class year, as demonstrated in Fig. 3. From the total participants, 62% were female and 37% male at ages of 14 (5%), 15 (12%), 16 (28%), 17 (43%), 18 (8%) and 19 and above (4%). 63% of participant students study at public schools, 37% at private ones and 1% at schools that are both public and private.

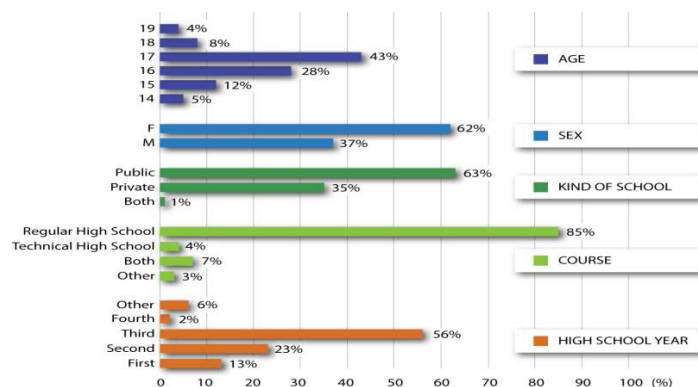


Figure 3: Characteristics of the 508 high students survey participants

In Brazil, high school education system consists of two kinds of schools: regular three year high school course, and 4 year technical high school course. Both of them certify students for finishing secondary education. But the technical schools correspond to training at secondary school level, including both levels 3 and 4 of the International Standard Classification of Education. It constitutes a form of vocational education, dedicated to the rapid integration of students into the labor market, with specific characteristics that may vary depending on the kind of course taken. However, some students do have the opportunity to take both of them simultaneously, in separate shifts. Survey participants indicated the kind of school they attend, resulting in 85% at regular high schools, 4% at technical high schools, 7% take both regular and technical high schools, and 3% study at other kind of schools. For this survey the option “other” for the kind of course they are at refers to students who already graduated from high school, but are attending special classes that prepare for entrance university exams.

Considering that in Brazil there is no freshmen high school year, the majority of participants were seniors (56% at regular high and 2% at technical schools), 23% were juniors, 13% were sophomore, and 6% probably study at entrance courses as declared “other” when filling out the year they study at.

The second part of survey assessed the students’ overall perception through a set of 47 six-point Likert-type scale questions in a hardcopy version. These close ended questions intended to measure students’ perceptions of how important some hard and soft skills are to succeed in the field engineering. Table 1 shows the list of skills students were asked to consider. They were asked to indicate the Likert-scale response that best represents how important to engineering they think each of the items (skills) are ranging from “very important”, “important”, “more or less important”, “little important” “not important”, to “I don’t know”.

The whole survey was intended to measure more than this paper is considering, so for the purpose of this paper, only part 1 related to the sample characteristics and part 2 related to skills importance to engineering will be considered and analyzed. Content data analysis of other parts of the survey will be released in future paper.

Table 1: Survey questions part 2.

code	Question	very important	important	indifferent	little important	not important	I don't know	code	Question	very important	important	indifferent	little important	not important	I don't know
1	Portuguese							24	Creativity						
2	Arts							25	Initiative						
3	Mathematics							26	Investigative spirit						
4	Chemistry							27	Persistency						
5	Physics							28	Socializing abilities						
6	Biology							29	Leadership						
7	Geography							30	Critical thinking						
8	History							31	Problems solutions						
9	Philosophy							32	Mathematical reasoning						
10	Sociology							33	Data analysis and interpretation						
11	Knowledge of how to use computers							34	Experimental/Lab work						
12	Programming knowledge/ programming languages							35	Multidisciplinary knowledge						
13	Oral and written communication							36	Entrepreneurship						
14	Texts reading comprehension							37	Decision taking						
15	Foreign language 1- oral and written English							38	Invention/Innovation						
16	Foreign language 2 - oral and written Spanish							39	Activities management						
17	Ecology / Environmental Sciences							40	Problems identifications, formulations and solutions						
18	Group work / group studies							41	Management and Business techniques						
19	Individual work / studies							42	Meet schedules, deadlines and targets						
20	Reading habit of daily news / world news							43	Applying Math, scientific and technological tools						
21	Reading habit of scientific literature							44	Technical drawings/Design						
22	Manual abilities							45	Spatial sense						
23	Curiosity							46	Electronics						
								47	Robotics						

4.3 Data collection

The University of São Paulo (USP) promotes an event called “USP and the Professions” twice a year where students all over the state can participate in a career day. During the 2013 “USP and the Professions” event (august 8-10), students were asked to voluntarily complete the paper-based survey.

For the sake of attracting students to fill out the survey, a poster was used with the following words “Do you want to win a tablet? We want to know what you think... answer a survey for a chance to win a tablet!”. Since the survey included no place for participants to write their personal information such as name, telephone number or e-mail contact, students were asked to fill out a small numbered sheet of paper containing these information, which were placed in separate box.

We collected the data during the event “USP and The Professions 2013”, where 508 high school students completed the paper-based format questionnaire. Answered questionnaires data were digitalized and analyzed the data.

In addition, the collected data is not representative of the entire Brazilian high school population, as this study did not cover the whole country high school universe. However, this information will provide deeper insights into secondary students’ motivations to pursue to tertiary education and, in particular, an engineering degree.

4.4 Analysis and results

Analysis was conducted in order to determine if high school students’ perceptions about skills’ importance to the field of engineering differ in terms of students’ age, gender, type of school, kind of course or year they are at. The primary data analysis techniques used in this study included a quantitative method of descriptive statistics analysis of the survey; categorizing themes using analysis matrix developed by the researcher, cross-case analysis; and triangulation to cross-check data accuracy. Throughout the analysis process, care was taken in the organization and interpretation of the data to ensure the transferability and dependability of this study.

4.4.1 Answers in numbers

All items that evaluated students’ perceptions towards engineering skills importance reflected a central tendency supporting that all soft and hard skills considered in this survey are important to engineering, no matter their age, gender, type of school, kind of major, nor the school year they are in, as shown in figures 4a and 4b.

Question number	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23
Very important	217	112	427	221	342	99	153	88	57	92	347	243	271	276	268	175	144	307	231	304	243	246	300
Important	174	133	58	146	93	123	169	119	84	97	116	130	129	132	145	153	187	142	181	117	153	167	129
More or Less important	61	130	6	89	45	138	106	141	131	121	21	56	64	61	62	115	103	31	50	53	58	55	37
Little important	34	81	4	25	6	72	36	90	116	107	5	30	13	13	14	34	32	7	17	11	20	10	15
Not important	3	28	2	8	6	39	21	37	81	50	2	8	4	6	6	9	15	1	4	3	12	4	5
Do not know	14	17	4	14	7	31	16	28	35	33	7	34	21	10	9	15	22	13	13	15	19	22	18
Blank	5	7	7	5	9	4	7	5	4	8	10	7	6	10	4	7	5	7	12	5	3	4	4
Total:	508	508	508	508	508	508	508	508	508	508	508	508	508	508	508	508	508	508	508	508	508	508	508

Question number	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42	43	44	45	46	47
Very important	346	403	211	360	259	299	278	361	888	326	202	197	202	318	310	276	297	157	352	348	280	208	237	203
Important	132	85	166	104	171	137	155	113	87	134	151	187	181	144	143	163	156	195	108	106	121	128	132	136
More or Less important	16	9	67	24	44	50	41	19	19	20	85	64	77	25	29	43	27	92	18	28	64	75	72	81
Little important	4	2	32	2	12	8	8	4	3	8	25	11	12	3	5	7	6	24	6	8	18	35	22	24
Not important	1	0	6	3	4	1	5	0	1	1	16	4	7	2	4	3	3	11	4	5	6	17	13	21
Do not know	5	4	19	7	11	9	13	6	4	9	21	24	21	8	5	12	10	20	8	8	15	39	26	38
Blank	4	5	7	8	7	4	8	5	6	10	8	21	8	8	12	4	9	9	12	5	4	6	6	5
Total:	508	508	508	508	508	508	508	508	508	508	508	508	508	508	508	508	508	508	508	508	508	508	508	508

Figure 4a: Answer results in numbers

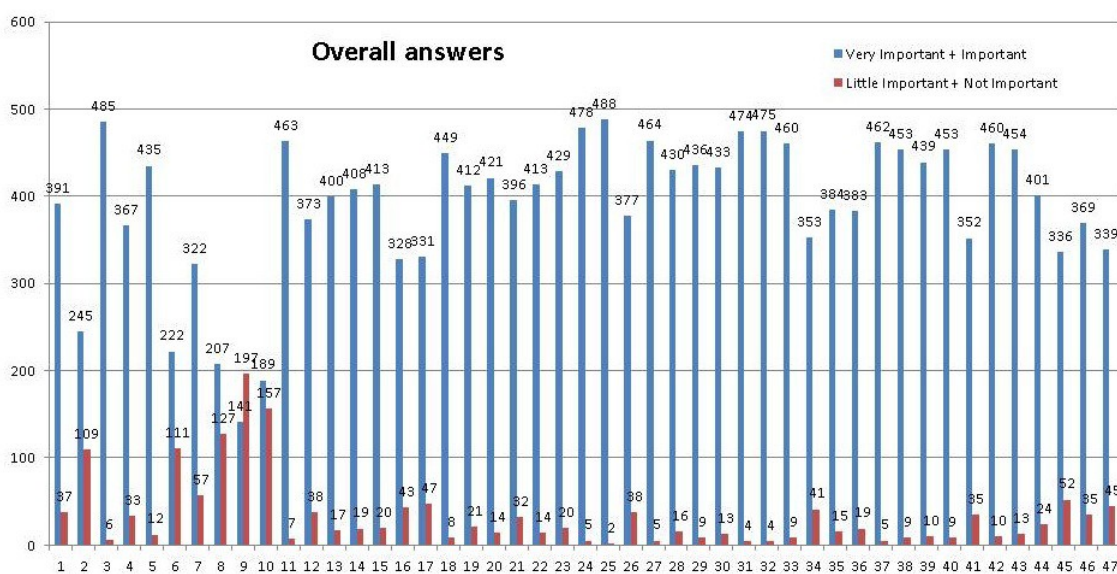


Figure 4b: Sum of answers considering the very important and important ones in one group (blue); and, little important and not important in second group (red)

Based on students' overall perceptions responses, mathematics is the most important technical skills to engineering (figure 5), and it leads in importance no matter the age, gender, school, year and school of all participants (figure 5).

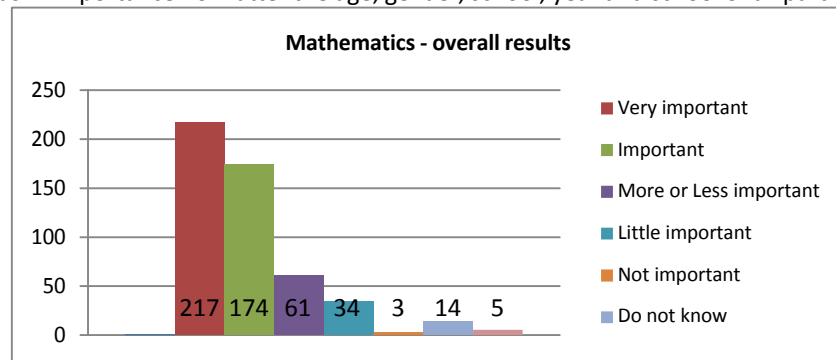


Figure 5: Mathematics – overall results

Following math, other skills were also considered more important to engineering like initiative, persistence and mathematical reasoning. On the other hand, survey data analysis shows that students' perceptions on the importance of sociology, philosophy, history and arts (figure 6) seem to be least important to engineering. The results corroborate to our thought that to be prepared for today's engineering, high school students need not only solid education in science, mathematics, and technology, but an education beyond high school subjects, including other solid enough foundation such as literacy, numeracy, and thinking skills to prosper in engineering.

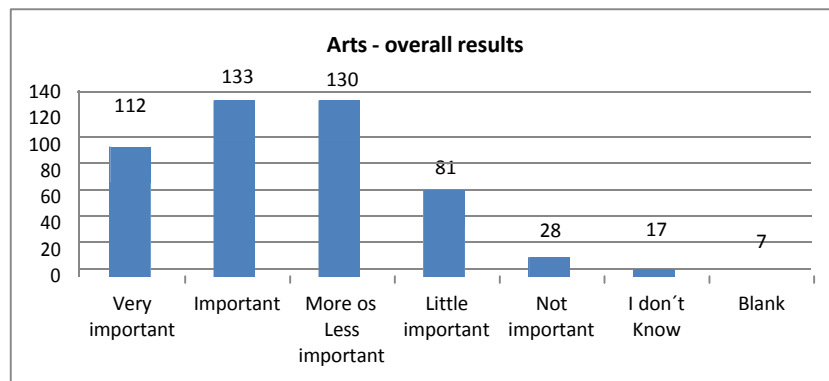


Figure 6: Charts showing students' perceptions on the importance of Arts to engineering

4.4.2 Normality Test (N-test)

Statistical tests have the advantage of making an objective judgment of normality, but are disadvantaged by sometimes not being sensitive enough at low sample sizes or overly sensitive to large sample sizes. And as an assessment of the normality of data is a prerequisite for many statistical tests because normal data is an underlying assumption in parametric testing, the Normality Test was applied to the 47 survey items.

In statistics, normality tests are used to determine if a data set is well-modeled by a normal distribution and to compute how likely it is for a random variable underlying the data set to be normally distributed. Therefore, as a lot of statistical tests (e.g. t-test) require normally distributed data, we should always check if this assumption is violated. The normality tests all report a P value (a probability, with a value ranging from zero to one) and the assumptions is: if the test is significant, the distribution is non-normal. Analyzing survey results, none of the variables have normal distribution, what means that if we would draw a graphic to represent it would not have a bell-like shape. Despite graphical method lacked objectivity in this study and it appeared to have a non-linear pattern, the numerical method results were considered even assuming that data failed the assumption of normality.

Using the traditional 0.05 cut-off to answer the question whether the data passed the normality test, the answer is "no", since the P value is less than or equal to 0.05.

4.4.3 Pearson Correlation Tests

Pearson correlation coefficient, can take a range of values from +1 to -1. Therefore, Pearson correlation test applied on the first part of the survey (participants' identification part), demonstrated there is no relevant correlation, since all values were very close to zero, where a value of zero indicates that there is no association between each of the two variables.

In addition, colors of the correlation test shown in Fig.7 data shows that the more red, the less correlation. In general, it reinforced there is no significant relation between the participants' survey answers. Note that column numbers start on seven because numbers 1 to 6 relate to the identification of the participants.

Pearson Correlation coefficient test (which is sensitive only to a linear relationship between two variables) showed very few correlations among the items, except for items 24 (creativity) and 25 (initiative). In item 24 there is a positive correlation showing that the ones who answered item 24 more positively, tended to do the same for item 25. This means that in students' minds, creativity and initiative are very strongly related.

Considering gender correlations, there were no positive correlations. Negative correlations related to COL36 (entrepreneurship) and COL 41 (management and business techniques) demonstrate that female students find them more important than male students do.

When considering the type of school, it has the highest correlation value (-0.16) with COL2 (Arts), even though a negative correlation. The majority of students from public schools think that Arts is important to engineering, while most of the students from both (public and private schools) did not find it important or did not answer it. However, there is a value of greater positive correlation (0,1) with the COL19 (individual work). Most of students from both schools find individual work/study important to engineering, while public school students find it not important or did not answer it.

	COL1	COL2	COL3	COL4	COL5	COL6	COL7	COL8	COL9	COL10	COL11	COL12	COL13	COL14	COL15	
Age	-0,02	-0,01	-0,09	0,12	0,04	0,07	0,10	0,09	0,05	0,03	-0,02	-0,04	0,02	0,05	-0,02	
Gender	-0,10	-0,08	-0,02	-0,08	0,03	-0,09	0,03	-0,05	-0,09	-0,09	0,03	-0,06	-0,07	0,01	0,00	
School	-0,04	-0,16	-0,06	0,04	0,06	0,01	-0,03	-0,03	-0,08	-0,09	0,04	0,09	-0,02	0,01	0,09	
Course	0,05	-0,02	0,05	0,01	0,01	-0,04	-0,06	0,00	0,00	-0,03	0,06	0,02	0,03	0,01	0,07	
Year in	-0,02	-0,01	-0,09	0,12	0,04	0,07	0,10	0,09	0,05	0,03	-0,02	-0,04	0,02	0,05	-0,02	
	COL16	COL17	COL18	COL19	COL20	COL21	COL22	COL23	COL24	COL25	COL26	COL27	COL28	COL29	COL30	COL31
Age	-0,07	0,06	0,07	0,05	0,00	0,07	0,02	0,08	-0,06	-0,05	0,11	0,02	0,07	-0,03	0,05	0,00
Gender	-0,03	-0,08	-0,08	-0,05	-0,05	-0,02	-0,07	-0,02	-0,07	-0,05	-0,06	-0,06	-0,07	0,01	-0,09	-0,01
School	0,02	-0,07	0,03	0,10	0,07	0,04	0,06	0,08	0,04	0,05	0,05	0,05	0,06	0,02	0,06	0,07
Course	0,03	0,02	0,01	0,02	0,09	0,02	0,07	0,02	0,05	0,05	0,00	0,08	0,03	0,05	0,03	0,06
Year in	-0,07	0,06	0,07	0,05	0,00	0,07	0,02	0,08	-0,06	-0,05	0,11	0,02	0,07	-0,03	0,05	0,00
	COL32	COL33	COL34	COL35	COL36	COL37	COL38	COL39	COL40	COL41	COL42	COL43	COL44	COL45	COL46	COL47
Age	-0,05	0,00	0,03	-0,01	0,03	-0,05	-0,03	-0,07	0,00	0,04	-0,02	-0,02	0,02	0,03	0,02	0,06
Gender	-0,05	0,00	0,01	0,00	-0,12	-0,06	-0,04	-0,03	0,02	-0,10	-0,02	-0,03	-0,02	0,04	-0,02	0,00
School	0,06	0,07	0,06	0,06	0,04	0,04	0,04	-0,02	0,01	-0,08	0,04	0,00	-0,06	0,02	0,09	0,06
Course	0,06	0,05	-0,01	0,01	0,03	0,04	0,05	0,03	0,05	0,07	0,09	0,05	0,03	-0,03	-0,09	-0,11
Year in	-0,05	0,00	0,03	-0,01	0,03	-0,05	-0,03	-0,07	0,00	0,04	-0,02	-0,02	0,02	0,03	0,02	0,06

Figure 7: Pearson analysis results.

Considering the kind of high school course (regular, technical, or other), we have the highest correlation as COL47 (robotics) negative (-0.11) and positively correlated with COL20 (reading habits of daily news/ world news) and COL42 –related to “meet schedules, deadlines and targets”- (0,09). Regular high school students find “reading habits of daily news/ world news” and “meet schedules, deadlines and targets” not so important to engineering, while students from “other courses” find them very important. And students from “other courses” do not know or does not consider robotics important to engineering, while regular high school students find it very important to engineering.

In relation to the year participants are in, a positive correlation was found in items 4 (chemistry), 7 (geography), 8 (history) and 26 (investigative spirit). This means that students in initial high school years do not know or did not answer these items, while students in last ones considered them important or very important.

In terms of age, COL26(Investigative spirit), COL7 (geography) and COL4 (chemistry) are positively correlated. This means that younger students do not consider these subjects so important to engineering or did not answer them, while older students find them important.

In order to verify students' perceptions of hard skills importance to engineering, the first 10 questions and 13 to 17 were related to high school subjects, while soft skills importance perception questions referred to other characteristics, abilities, competencies and qualities for engineering. When data was analyzed, the students tended to have similar responses. According to students' perceptions, mathematics and physics are on the top list of most important hard skills to engineering, while history and philosophy knowledge are the least important, as shown in figure 5, where pivot table charts confirm it. Related to soft skills, student's considered initiative and mathematical reasoning the most important ones to engineering. Overall results demonstrated that high school students perceive how important hard and soft skills are to engineering.

Other correlation coefficients are being developed to be more robust than the Pearson correlation, that is, more sensitive to nonlinear relationships.

5 Discussions and Conclusions

To be good at hard skills it usually takes smarts or IQ (“intelligence quotient”); and to be good at soft skills it usually takes emotional intelligence or EQ (“emotional quotient”) (Han, 2011). Since EQ is really about soft skills, and IQ relates to hard skills, there is probably no way to succeed in professional life without combining both of them. In other words, the combination of individuals IQ and EQ ensures career success.

In this rapidly changing world, hard skills are being considered as important as soft skills. Contrary to hard or technical skills learned in educational programs with classroom instruction and practical training, soft skills are not often learned in regular or traditional schools. They have to do with emotional intelligence, and enable professionals to navigate smoothly and efficiently through a wide variety of social and professional situations with a wide variety of people.

No matter how it is called, “soft skills”, “pervasive qualities”, “enabling competencies”, among others, the focus approach should attend expectations in terms of learning and outcomes, or what an individual can do or accomplish, rather than in terms of acquired knowledge. In other words, they focus on the application and not on the acquisition of knowledge as soft skills can be learned with practice, time and guidance. Since the breadth of knowledge necessary for engineers in training to be successful requires a wide range of hard and soft skills, active learning is an excellent way to increase these skills.

As any other area, engineering technical acumen alone is no longer sufficient for engineering career success, and soft skills have played an important role in differentiating STEM professionals for employment and advancement. Some specific skills, attributes and qualities have been suggested to the engineer to practice effectively in a professional manner. It is expected that an engineering degree program will foster, develop and inculcate such attributes, skills and qualities, such as the ones listed in the Subject Benchmark Statement under five headings - Knowledge and Understanding; Intellectual Abilities; Practical Skills; General Transferable Skills; and Qualities - (Maddocks et al 2002).

No matter the career choice will be, students need to start planning in high school to ensure they are prepared to take the right course later at university. Some specific profile tests may help as a starting point for students to gain a better understanding of their interests, values and goals, allied to discussions with friends, family or professional career practitioners at school or elsewhere. Regardless of what kind of career students might think of doing – and engineering is no different – it is important to keep all their options open when studying, not putting aside some specific technical or specialized skills required for each career. There are some technical or specialized skills required for an engineering successful career which enable them to take up engineering.

When considering engineering as a career choice, excelling in mathematics and additional related subjects such as chemistry, physics or higher math subjects will surely benefit the candidate. It is not easy to decide whether engineering is the right career choice, but a good way to start it is to work out personal likes, enjoyed subjects, added to some technical skills (maths, science, computer skills) and transferable skills (communication skills, teamwork, technology, critical thinking, etc.) needed.

Even though some skills can be discovered and developed within an engineering curriculum, some basic skills may be a shortcut for a “painless” education instead of just wondering whether high school students will be successful or not in engineering. However, successfully delivering the skills for the future knowledge economy will depend not only on producing the right number of high school graduates, but also on the system supplying them with the right knowledge, competencies, and qualities.

It is not easy to educate an engineer prepared to meet the challenges encountered in this new century, but encouraging high school students to pursue a career in Engineering is crucial in building a strong foundation for a successful future nation. A report from the US National Academy of Engineering (NAE, 2013) says that encouraging young people to make a difference in the world through an engineering career is more likely to attract them than emphasizing the challenge of math and science skills. Therefore, there is an urgent need for initiatives to strengthen and improve mathematics and science teaching in the levels of primary and secondary education.

There is a need of stressing pre-engineering high school required skills in order to enhance success during engineering university level courses, and also making it more clearly to high school students how important some skills are to the engineering career. The knowledge of the importance of its skills may be a path to help attracting not only in numbers but in better skilled students to enter university engineering levels.

Besides research revealing that high school students do recognize the importance of some skills to succeed in the field of engineering no matter their age, gender, school, course or year they are in, this paper also aims to contribute to the issue on active learning as an excellent way to increase soft and hard skills, since the breadth of knowledge necessary

for engineers in training to be successful requires a wide range of both hard and soft skills. We believe that active learning is a path to promote a true impact on skilled future professionals, particularly engineers.

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Activities to approximate University and High School

Mario Sergio de Oliveira Jr.* , João Paulo Bertolini Sehn* , Christian Joezer Meirinho* , Gustavo Carlos Knabben* ,
Gustavo Bernardo de Oliveira* , André Bittencourt Leal*

*Departamento de Engenharia Elétrica, Centro de Ciências Tecnológicas, Universidade do Estado de Santa Catarina, Joinville, SC, Brazil
Rua Paulo Malschitzki, s/n - Campus Universitário Prof. Avelino Marcante - Bairro Zona Industrial Norte

Email: mariosergio.o.jr@gmail.com, joaosehn@gmail.com, cviolino@gmail.com, gustavoknabben@gmail.com, maisumgustavo@gmail.com

Abstract

This paper presents some activities developed in the Electrical Engineering Department of the State University of Santa Catarina to approach high school students and college. The methods that are used allow showing to these students with content and knowledge from the university how the academic career can be interesting and exciting. Using this approach, the action can motivate students to continue their learning career after the completion of the high school in the university. The article contains a detailed analysis of the results that were conquest and proposes future jobs that can improve more and more the active learning to attract high school students to the university.

Keywords: High School; Engineering; Experimental classes; Robotics.

1 Introduction

In Brazil, according to 2007-2011 data from INEP (National Institute of Educational Studies and Researches), only 17 % of the students from the basic education enters in the Higher Education. Of those 17 %, according to the Observatory of Engineering Education in Brazil, provided by Federal University of Juiz de Fora - UFJF (UFJF, 2009), only 8.79 % students choose engineering courses, against 23.2 % that prefer to study Administration and Law.

Table 1: Students enrolled in Brazilian education

Level	Total inscriptions	Relative inscriptions (%)
Basic Education	30.358.640	100
High School	9.393.876	31
University	5.191.760	17

(BRASIL, 2007-2011)

This fact confirms - or, at least, it helps to understand - the low demand of high school students for engineering courses. High school students prefer Human Sciences to the Technological Sciences as their professions for the future.

Table 2: Courses more chosen by students

Course	Enrollments	
	Total	Relative (%)
Administration	200.737	13,28
Right	149.377	9,88
Engineering	132.839	8,79
Pedagogics	81.068	5,36
Technologists	46.006	3,04
Medicine	17.339	1,15
Other	884.022	58,49
TOTAL	1.511.388	100,0

(UFJF, 2009)

The growing demand for engineers is due to its fundamental importance in the country's growth. In Brazil, it is remarkable the lack of professional engineering, since a great part of Brazilian higher education's focus is not in that area.

Comparing Brazil with other countries, it appears that the current situation is unsustainable. The relationship between the numbers of engineers per total number of inhabitants is worse than expected in comparison to the most developed countries and even the same level of development. According to the OECD (Organization for Economic Cooperation and Development), in a total list of 35 countries, Brazil is the one with the lowest percentage of graduate engineers per 10,000 inhabitants, with a ratio of only 1.95%. Table X shows the relation engineers / 10,000 inhabitants of some countries. (DA SILVA et. al., 2011)

Table 3: Relation Engineers/10,000 inhabitants

Coutry	Engineers/10,000 inhabitants (%)
Brazil	1.95
Chile	4.07
USA	4.60
Germany	5.10
Mexico	5.40
Canada	5.45
United Kingdom	7.57
Australia	8.03
France	8.68
Japan	10.24
China	13.41
Portugal	13.86
South Korea	16.40

(OECD, 2010)

It has been difficult for high school students to choose to study mathematics and physics currently where they can select lots of options that seem to be easier or funnier than engineering. It happens because the labor market is more and more opened to different careers and an engineer profession is generally considered as a difficult one and without motivation.

In a growing country, as Brazil, it is necessary to graduate a large amount of engineers to have technological and infrastructural development. The basic education and the high school teachers, however, have not motivated students to pursue an engineering career.

In an attempt to decrease the problematic previously presented, a program, which has the objective of attracting high school students for engineering courses, was created in the State University of Santa Catarina. The program is called Include with Science and Technology and is based on the contribution of (TIBA, 1996), that presents the following reflection: "Receiving some tasty meal, the desire to eat comes. Attractive information produces a similar result: the more people know, the more they want to learn." High school students, through this action, might have contact with themes and practices that involve the engineering universe in a playful and fun way. The main idea is to provide them an opportunity to improve their learning by the following activities that remind some Engineering Course's knowledge.

Logic, creativity, teamwork and others skills are developed by classes using the Lego NXT robotics kit. Physics subjects are reviewed and efficiently understood through experimental activities which let the students excited. In addition, visits to the university are programmed, where some laboratories are shown and lectures are given, presenting different engineering courses. These actions reveal a possibility to increase the high school student's preference for Engineering course by activities that motivate and shows then the funny and exciting part of being an Engineer.

1.1 Motivation

In order to achieve more and better engineers, it is necessary to spread the role of engineering courses as well as promote integration of interdisciplinary studies in courses. In the same way, for economic development, it is necessary

optimization and innovation, as these are directly involved to engineering. Thus, plans to make high school closer to university are directly related to the development of the nation. (GAIER et. al., 2012)

Beyond that, as a student, it is important to have at least a sense of what will be performed in the future - not only in a technical field, but also as civilians. Therefore, to prepare the students to another political, social and economic context is more than a desired complement: it is a proof of maturity, engagement and an excellent bet in looking for a successful professional actuation. (KNABBEN et. al., 2013)

2 Methods

In this section, the methods used in proposed activities, which improves active learning to attract high school students to Engineering, will be presented. It is separated in three basic activities: robotics classes, physics classes and scientific exhibitions that will be explained in the sequel.

2.1 Robotics classes

The “Robotic and education” project aims to increase the education high school’s level class by involving robotic and logic to teach physics, mathematics and other knowledge’s. To achieve this goal, some academics students are selected to start to learn the Educational Robot Lego kit at the university as a non-curricular activity, developing the knowledge studied in class in a practical and active way with a professor’s help. After that, the academics are ready to teach the High school’s students and teachers.

These classes are planned to motivate the students to develop their logic knowledge, teamwork, planning and problem resolution skills by using the Problem Based Learning (PBL) idea. Barrows (1996) explains some topics about the PBL: the learner ship happens in groups with a tutor orientation, which is the one who helps as a facilitator and problems are a way to develop skills for its solution.

2.1.1 Educational robotics kit

The project uses Lego Mindstorms NXT kits as the main tools in classes. This kit, released in 2006, was conceived to be an educational tool to teach the basics of robotics and programming. It’s simple block language allowed this kit to be used with children since their first grades, focusing on the problem solving itself, as the programming language is intuitive and visual.



Figure 1: Group of students learning robotics

The kit has a good variety of components, as shown in Figure 1. The main block (1) is the central unit, being responsible for all actions. Sensors are also shown: the touch sensor (2), sound level (3), light level (4) and ultrasonic (5). Each function gives a degree of freedom in the problems, stimulating the creativity to solve the same problems in

different ways and also giving the teacher freedom to create many different situations to be solved and, thus, to make more dynamic and challenging exercises. The kit also has servo motors (6), which are the responsible for the robot's movements.

2.1.2 The classes

Following some of barrow's ideas, we split the students in groups whose tutors are the trained Academics. First, basic concepts are taught and, after that, a problem is given. The tutor's works to lead the student to think what he would do to solve the problem and then think in each step from the beginning until the problem is solved. After that, the student is able to build and implement the algorithm in the robot. When the task is solved, the tutor explains a new concept and then increases the next problem's level.

Physics and Mathematics can be easily taught using robotics, which could certainly stimulate the students to keep learning the subjects and to get closed to these science and engineering. According to Lima and Magalhães (2013), applying the proposition to teach using robotic, 80% of the high schools students said that, after this, they had a better performance to solve circular movement's problems in physics and Math classes. Lima and Magalhães (2013) also reported that 78,5% of the technical high school students said that they have more motivation to entering in an Engineering College after the robotic classes.

In classes which already work well, these kits could be used to make an even better experience by improving the idea presented by Lima and Magalhães (2013). A bigger number of physics and mathematics experiments can be developed to teach then using educational robotics kits.



Figure 2: Group of students learning robotics

For didactic purposes, a booklet was made by the former project members in order to help both teachers and students during the class and it has been reviewed and changed since then to make it even better to the next classes. The booklet contains the theoretical part of the subject, followed by fixation exercises - easier in the beginning, but getting increasingly harder as the student goes on.

2.2 Physics classes

The "Science for Everyone" project aims the society's inclusion through the dissemination of knowledge linked to science and technology, as well the motivation of the Basic and High School students to attend College courses. This is done through technical exhibitions in public places and practical activities not generally provided in the academic schedule.

Brazilian high students do not have much contact with the engineering areas before entering in university. Thus, a way to show them a bit of engineering is to give classes about basic engineering subjects, interacting and motivating them

to get closer to university. Moreover, the interaction of high students with college provides a knowledge exchange which aggregates in both directions.

These classes have the objective of raising the student's interest at exact sciences. By encouraging the learning, the students are stimulated to keep studying and to join University without having fear of physics and math. Through the implementation of these experiments, it is expected to elucidate the theory presented by the teacher in the class (OLIVEIRA et. al., 2011).

Classes for high school students about basic electrical engineering physics are given, leading theory, practice and curiosities to the classroom, bringing different activities than those which the students are used to have. This relation between the theory that students have in the classroom and the practical activities that the project provides improves the students learning and their interest in the subjects.



Figure 2: Project member assisting students in practical activity

Physics classes are held periodically at many schools around the university. They are planned and executed dynamically, through experiments, in partnership with the school teachers and each edition is optimized to enhance the student's experience.

In each class, the students have contact with areas such as electromagnetism, association of resistors and other contents treated in courses of electrical engineering. Thus, the students get a contact and motivation for usual university activities.

2.3 Scientific exhibits

Another way of disseminating the technological and scientific knowledge is to provide moments during the scholar period of a High School student in which he can experience something different and new; something that is not in his daily routine and which is developed in university. This is the purpose of doing several public displays of basic prototypes, which gives the students an opportunity of knowing some projects developed in an Electrical Engineering course.



Figure 3: University students presenting some projects to High School students

These scientific exhibitions are realized to motivate students of elementary and high school to college, preferably an engineering course. The prototypes presented are quite interactive and include homework's built by engineering students in disciplines of the under graduation course itself. It also provides a knowledge exchange: school children are introduced to a new universe full of possibilities while college students can see how interesting their projects are for other people even when they seem to be simple from their point of view, which motivates both of them.

This activity happens in public places like squares, schools and professional fairs where science and technological events are being realized. The exchange of knowledge that occurs in these rich moments is very interesting because it combines the creativity of young students with the expertise of the university.

3 Analysis and results

Activities in partnership with high school teachers are being held since 2010 and it has been showing great results. Classes in high school are already a consolidated activity; partner teachers are opened to keep the project with university, since the difficulties of high school to do practical exercises with students stemmed from a lack of material and time, which we do for them.

As shown in the previously topics, to teach using educational robots as a tool has been an expressive way to improve the learning and the high school students' performance. By this way, the State Government bought those kits to some schools 2 years ago, but they were not being used because the teachers did not have the training to do so. A few number of teachers had already been trained by the academics, so a partnership is in development, to give this training to more than 200 teachers from the State's High Schools. This is a wonderful opportunity to reach a larger number of students, because these trained teachers will be able to train more students each year, increasing the range of the classes and creating a "multiplier effect of knowledge", as presented by (MEIRINHO et. al., 2012).

The Lego Education has some great educational kits, but not all of them are ready to be applied in Brazilians schools. There is a need to adapt to our way of teaching and learning. So, there is a need to adapt it, developing new experiments in physics, mathematics and others sciences.

The other line of the project, which gives physics experimental classes for high school students, proved that is an excellent opportunity for this people to learn something different than the traditional theoretical classes. Because it is done in schools that doesn't have an appropriate laboratory structure for practical classes, the experiments brought from the university are a wonderful solution. They can be easily and fast applied in any room that the school offers because they are modular and easy to mount.

During the scholar period of 2013, physics experiments were applied in three different schools of the city. Two meetings were realized in each one. A total of 156 high school students participated in the activity and learned something practical about physics, awakening the interest for engineering courses.

As a future job, the project intends to use the same idea of the robotics classes: to create a "multiplier effect of knowledge". The physics experiments will be constructed in the university and donated for the school to apply as some practical classes by the teacher of the discipline. The project will give entire support for the teacher to apply the experiment in a better way, including the use of video-classes to explain its operation and implementation.

Using this approach, it is possible to let the activity "walk by its own legs" and the project just participates in sporadic moments to evaluate the progress and to propose improvements.

The scientific exhibitions also helped to motivate students of different ages to consolidate the idea of studying and enter in the university as the best option for a better professional future. Four scientific exhibitions were promoted in different public places and a total of 705 students were motivated by the university activities.

4 Conclusion

The actual Brazilian situation, talking about education, has a complex context. The scholar evasion was always a problem for the country and lots of possible students lost their opportunity to continue in an academic career. Statistical researches reveal that, in engineering, the problem is even worse. A great part of high school students does not want to continue their studies in engineering courses, mainly because mathematics and physics are not attractive subjects and the students do not have the opportunity of knowing better about what these engineering courses can propitiate.

Since the moment that the community is presented to these activities listed in the projects, it has grown its interest about the presented subjects, showing that we need to carry out projects that arouse the interest for this knowledge within communities. Also, a relevant point is that our activities had already begun to emancipate from our projects, creating a "multiplier effect of knowledge" to make its effective range even bigger than before. There is still some road to go, but the first steps towards a new teaching approach in high school classes had already been given with positive results.

Therefore, the projects presented here seek to motivate high school students to enter the university, improving education and increasing as whole the quality of the country.

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Student Contests as Motivation for Engineering

Kurt André Pereira Amann*

* Department of Civil Engineering, Centro Universitário da FEI (FEI University), São Bernardo do Campo, SP, Brazil

Email: kpereira@fei.edu.br

Abstract

This paper presents some experiences proposed by FEI University, Brazil, using student contests to attract high school students to Engineering and to prevent the evasion: the "Travessia-FEI" contest and the "ComPET". The first began as an internal contest to engineering students and other courses, after opened to high schools students. The second is an external proposal to develop competitions in high schools, based on FEI's experiences, with the process available by Internet site to multiply the proposal. Considerations about evaluation of the proposals effectiveness are then discussed.

Keywords: contests; engineering activities to high school; active learning and hands-on activities

1 Introduction

Many efforts have been made worldwide to increase the number of students in engineering courses, seen to be a strategic area to keep a country in a competitive economic position. In Brazil, this situation is not different, and the Government has fostered public notices, as "FINEP - PROMOVE - Engineering on High School (05/2006)" or, more recently, "CNPq/VALE S.A. Nº 05/2012 – Forma-Engineering", with this intent. In both of them, FEI University had projects contemplated, being the first reported by Barbeto and Schuetze (2008) and the second will be presented later in this paper.

On the other hand, FEI University has a long tradition of participation in student contests and competitions, promoted by some organizations, in many engineering areas as Textile, Materials, Civil, Industrial, Mechanical, etc. These experiences, which began in 1995, as well as FEI's laboratorial infrastructure to support them, were reported by Miranda et al (2010) and were the basis to develop the previously mentioned projects.

In this context, this paper aims to present two specific FEI's proposals of student contests: the "Travessia-FEI" (Crossing-FEI) contest, in which the students construct bridges with popsicle-sticks, and the "ComPET" or "Platform to Develop Competitions about Structural Models with Recycled Materials". The first is an internal contest, also opened to high school students, and the second is an external proposal, supported by the Forma-Engineering public notice, involving a public high school in São Bernardo do Campo. These two experiences are presented below.

1.1 Motivation

Attracting young talents to Engineering is perhaps the biggest challenge of the university education. It starts with the difficulties in Mathematics and Physics at high school (Prieto et al, 2009 and Roberts, 2002) and it continues in the university life. To reverse this situation, a way to motivate the students is the competition projects, as the Harvard University experience reported by Sadler et al (2000), in which the students should research and find solutions to engineering problems, and the best project that meets the established criteria may win. On the other hand, by presenting their solutions through construction of prototypes (hands-on activity), the students develop motivation to learn (Blumenfeld et al, 1991), being an active learning approach.

1.1.1 Previous experience of FEI University with high school activities

In this way, FEI's proposal to the Brazilian Government public notices "FINEP - PROMOVE - Engineering on High School (05/2006)" was the JOVEM (Journeys to Valorizing the Engineering in High School) program, with projects on Mechanical, Electrical and Chemical engineering areas, involving 120 students and 11 teachers from two public and two private High Schools (Barbeto and Schuetze, 2008). The Mechanical project was the construction of little motorized cars to compete in a car race, named Formula-FEI; the Electrical project was to construct robots to compete in a robots race and the Chemical project was to develop a bio-fuel from soybean oil. In the second year, some changes were made: the students should produce premium gas to the cars, and the car competition considers the autonomy and not the speed. In the Electrical project, two different teams should cooperate to make a parade of allegorical robots, named Robots Carnival (Barbeto and Schuetze, 2009).

1.1.2 Structure competitions

Particularly, in the engineering courses, Structures is one of the main areas in which the knowledge on Mathematic and Physics subjects is most applied and, additionally, if the student doesn't have practical experiences about structural behavior, he will have great difficulties. And it's important to remember that all kinds of engineers should have knowledge on Structures. So, the hands-on and active learning proposes are very interesting to be applied in this context, and, if the student is presented to these concepts in high school, his engineering ability can be awakened.

In this context, an uncountable number of structural competitions can be found worldwide, most of them about bridges built with spaghetti or popsicle-sticks. In Brazil, a very interesting experience is presented by Napoleão Filho (1997), in "FINEP-REENGE" context, an old Brazilian public notice dated 1996, applied to engineering students that already have knowledge in structural theories, civil construction materials and including bridges design. Other contests in many parts of the country can be evaluated too.

Analyzing all this information and thinking about how to motivate the students by a contest which reflects the way that things are done at FEI, i.e., innovative and challenging, the author proposes in 2009 the first "Travessia-FEI" contest, and after, in 2012, the "ComPET", as follows.

2 The "TRAVESSIA-FEI" Contest

Here follows the development of the "Travessia-FEI" contest idea. The FEI's proposal of bridge contest was designed to be innovative and very stimulating as can be seen. It can be said that there is no bridge competition around the world which can be compared with this one.

2.1 Conception of the structure

Thinking about structure contests to motivate students, bridges are very interesting because they always attract attention: people want to cross the bridge to see what is on the other side; hence the name of the contest: "Travessia" (crossing). Indeed, this aspect, the crossing, was strongly considered on the proposal, as it will be presented later, performing the absolute differential of FEI's contest.

Other reasons to bridges which attract people's attention are: they transpose large spans, and nowadays the spans are getting bigger; many old bridges worldwide are still in use today, as some of those were built in Roman times in Europe, challenging the time; nowadays, the technology used for its construction is very inventive, because they can be built on the bed of a river with its natural flow. But mostly they are called civil artworks, in which the aesthetic beauty is requisite: a bridge should also be a postcard.

So, bridges are a good choice to a structural contest, incentivizing the students to research more and more about their constructions, structural conception and aesthetic. Moreover, to keep the contest ever interesting and surprising, FEI's organizing committee should annually use creativity to modify not only the size but also the kind of inspiring bridge projects, and the students should research about them and present their findings on posters. In the "Professional Category" (PRO), the engineering students must still demonstrate all structure calculations.

2.2 Materials

2.2.1 Structural material

According to the author's researches, the most common material to student bridge contests is spaghetti, followed by popsicle-sticks (wood). Spaghetti draws attention because it is an unusual and brittle material, i.e., it's a food. Without wishing to belittle the choice of the spaghetti bridge fans, particularly, many people around the world suffer from hunger and food doesn't seem appropriate to be used for this activity. On the other hand, wood is a renewable resource, because the CO₂ released with its burning is the same as that removed from the atmosphere during trees' growth. So, the popsicle-stick was the chosen structural material.

2.2.2 Adhesive material

Regarding the glue type, PVA glue is soluble in water, being less aggressive to the environment, and so it's the preferential glue provided by FEI, but it becomes needed two days to hold the contest: assembly the bridge in the first day, after are needed twenty-four hours to cure the glue, and, then, load test in the second day.

However, considering how important the material research is, other types of glue can be allowed, except epoxy mass, polyurethane foam (PU), being forbidden to create resin crusts over the popsicles too.

2.2.3 Other materials

Alternative materials as raw cotton strings and metallic paper clips have been incorporated in the last years to enhance the creative freedom of the students and allow them to build the different types of bridges proposed each year. It's another differential of the FEI's bridge contest.

In the PRO category, the engineering students must test all materials and use the resistant value obtained in their calculations.

2.3 The contest categories and teams composition

The first "Travessia-FEI" contest in 2009 was thought to reduce the evasion motivating the FEI's engineering students to research and apply their knowledge, acquired at classroom or not (manual skills), on an engineering project, i.e., building the popsicle-stick bridge. However, it was important to consider that the freshman students don't have the same knowledge that a senior student has, and it would also be important that students from other FEI's courses (Business Administration and Computer Science) be included, to promote integration between them. Also, two categories were created: ABC category, for freshman engineering students and other courses, and; PRO category, for engineering sophomore onward. In the first contest, fourteen teams registered for the contest, being ten to PRO category and four to ABC, but respectively seven and two teams effectively participate (64% of proposal efficiency).

2.3.1 Interdisciplinary teamwork skill

In the PRO category the students was incentivized to create teams in which the members were from different engineering areas (i.e., civil, mechanical, electrical, textile, industrial, chemical) and different course levels, to promote different skills and interdisciplinarity in the teams. In the ABC category teams with members from different courses were allowed, too. Thus, it seeks to promote interdisciplinary teamwork skill, which is one of the contest's goals.

2.3.2 Team width

The number of team members was another important decision to the organizing committee, because a lot of people in the same team can disrupt the process. Some competitions researched have six or more members, others, as some spaghetti competitions, are individual. Analyzing the intended goals, two to four members was considered adequate in FEI's contest. Individual teams (only one member) are not interesting because so it lacks teamwork, considered an important skill in the contest.

2.3.3 High school participation

Having in view the mentioned previous experiences of FEI, and some competitions researched, in the second edition of "Travessia-FEI" the contest was opened to High School students, in a new category titled EMC. The rules were identical to ABC category, but the most students became external to FEI.

So, in 2010, fourteen High Schools registered for the contest, performing an incredible total of fifty-one teams with four students each, being twenty-four teams (47%) from the same school. It's important to note that many schools were on the waiting list, because the vacancies were limited to sixty, being twenty per turn (morning, afternoon and evening). These three turns of the contest are designed to allow the student not to miss classes, and be able to participate in counter-turn. However, only nine teams were registered from FEI, being five to PRO category and they deserve further considerations below.

Actually, forty-four teams from High Schools and six teams from FEI participated, with efficiency of 84.6% and 75%.

2.4 Time to assemble the bridges

Some competitions researched establish five to eight hours to assemble the bridges, or the bridges can be brought directly from home. In FEI's bridge contest, teamwork was considered to be absolutely important, as well as the research for the best solution, the project, the careful design of details, the prior planning, thinking about the construction methodology, the training to build and meet a short deadline, and using creativity in constructive solutions.

Also, to enable experience with all these aspects at their limit (and also to meet the three assembly turns in a day), it was established four hours to assemble the bridges. In fact, this is a very short time to build a bridge with four members only, which requires much planning and training (see figure 1), also considering that the bridge width has increased in the last years, since from one meter to one meter and thirty centimeters, and now with one meter and sixty centimeters long.

Then, a winning bridge will hardly be built with improvisation, likewise requiring jigs, clamps, curing accelerators to the glue, cutting tools and other creative resources to have a good performance. FEI's proposal leads to limit the dedication to deadlines with quality, being another differential.

Unfortunately, some bridges stick on the ground, other crumbles when transported for storage, but it's part of the proposed learning.



Figure 1: Students researching (left) and training the assembly (right) in laboratory

2.4.1 Collaborative work experience in a competition

Recognizing that these mentioned failure situations are very hard to some students, and that competitions may seem risky for a proposal involving learning, whereas performance differences between teams may discourage participation in the proposed experiment, it is clear that the feeling of the people must be considered. In this context, Barbeta (2010) cites Brotto (1999) who verifies that to compete and to collaborate are distinct processes but they can be complementary and not antagonistic. Then, the proposals must therefore learn dosing competition and collaboration for a better result. This is even more important, considering that FEI University is a Catholic Institution that follows the Jesuit principles of human values and social justice. Because it also students donate food to enroll.

Therefore, FEI's bridge contest has a collective goal: all the teams from every turn must at least complete the bridge deck, to be able to be tested. If one team has not completed at least the bridge deck, all teams of this turn lose 10 points. At the same time, the teams are encouraged to collaborate with each other to finalize all the decks, getting votes to elect the more collaborative team of the turn.

This may be controversial, because they can vote for themselves, but it is also an ethical exercise. In fact, it can be viewed that the teams collaborate, lending their tools, and personally helping the other competitors when their own work is practically finished. Thus, even though the team later completes their deck, when there is evidence of collaboration with them, the organization committee may spare penalty to the turn.

2.5 FEI's innovation: test conception and test device development

Everything was presented so far is not in fact an innovation, only insightful decisions to define some specific differentials for FEI's contest. Maybe, the greatest innovation of this contest is the new concept to test the popsicle-stick bridges resistance: the dynamic test with mobile loads.



Figure 2: A bridge before the test and a student with safety equipment (left); a view of the PONDEMIBILATOR (right)

Absolutely all competitions researched by the author perform the bridge tests applying static loads on their central point. So, thinking of originality and innovation, inspired by the "Autoinfluencegrapher" (an old test equipment to obtain the influence line of complex acrylic bridge models, developed in the sixties by a Portuguese bridge engineer named Edgar Cardoso), the author created a new test equipment to apply mobile loads: the PONDEMIBILATOR® or mobile loads applicator (see figure 2, right).

The PONDEMobilator[®] is revolutionary, innovative and is the only one in the world, because it is the first equipment developed to test popsicle-stick bridges, allowing a little standard truck (trolley) with live load to cross the bridge from one side to the other; hence the contest name “Travessia”. Then, the contest goal is to cross the bridge leading the load to the other side: if the bridge support the load, the crossing is completed, otherwise, the previously applied load is considered the greatest load supported by the bridge.

2.5.1 Characteristics of dynamic test with mobile loads

With the PONDEMobilator[®] the popsicle-stick bridge tests are much more exciting, because they gain innumerable failure forms. As the loaded trolley moves up the bridge, it is possible to see if the bridge supports the shear load, or if the deck will suffer puncture due to the trolley’s wheels; when the trolley isn’t properly aligned, it can deflect causing twist and damage in the lateral bridge structures; when it gets closer to the center of the bridge, crackling can be heard and it is possible to see the parts of the structure being deformed, causing the students to reduce the speed, however they can’t stop because they must finish the crossing; depending on the glue stiffness and the structure slenderness, the bridge is very flexible and it does not break, but it is so deformed that it moves and loses support, falling but remaining almost intact.

In the PRO category the students must calculate the failure load, predict the failure mode, also predict the load to lower the deck twenty millimeters, and earn more points if it comes closer to the test result.

2.5.2 Safety on the tests

Some competitions researched pose risks to the students. The principle of PONDEMobilator[®] design is to ensure safety against accidents at the instant of bridge failure. Still, students must wear helmets to handle the equipment safely, which does not occur in other competitions (see figure 2, left).

2.6 Evaluating the teams

“TRAVESSIA-FEI” is a contest, not only a competition or championship, because many team skills are evaluated, not only the biggest load supported. The bridges prototypes are also evaluated by their aesthetic and creativity, during and after their assemblies and the teams are evaluated for their cooperation with other teams.

However, the weightiest requirement on the contest is still the “structural efficiency factor”, i.e., the ratio between the load supported and the bridge weight. In this way, the number of popsicle-sticks is not controlled, giving freedom to the creativity, but the teams should use them with criteria, researching the most efficient structural system, because a weighty bridge that supports a heavy load can lose to other lighter ones that support proportionally more load.

Other specific aspects are also evaluated by the organization committee (at least three professors are invited) and according to team category:

2.6.1 ABC (freshman and other courses) and EMC (High School and Invited) categories

The teams should research about the proposed bridge type of that year and each one should elect a real bridge to be their inspiring project. This inspiration must be presented as a poster, explaining how the team will build the bridge, and their structural solution. The posters are evaluated by the clarity of information, aesthetic, and creativity, promoting visual communication skills.

2.6.2 PRO (sophomore onward) category

In PRO category, the teams must also research about the bridge type and choose an inspiring real bridge, but they must still present a technical report with the detailed design, all structure calculations, obtaining the load failure and failure mode, as well as the load to deform twenty millimeters. These are engineering project requirements and make an accuracy factor that multiplies the structural efficiency factor in the team score.

2.7 Student participation analysis

Analyzing the student participation in the contest (figure 3a) it is verified that the high schools’ participation is bigger than FEI’s students. This large amount of High Schools registrations (around twenty per year) and still the waiting lists (ten to fifteen more schools), since the first contest opened to them, deserve attention and can show the pent-up demand for such activities in schools.

On the other hand, analyzing the small number of FEI’s students participating (approximately three students for each thousand students) it’s possible to think that the engineering student is not interested in contests, but in fact, it reflects the weight of the classroom activities in Brazilian engineering courses: many students were not receiving their awards at the official handover because they had to go to classes at the Physics lab, for example. In general, the students attracted by contest were students of good academic performance. It makes one wonder: the average

student that needs to develop these skills, as proposed in the contest, is certainly in the classroom all the time and has no opportunity to explore his creativity. “How can we do this?” continue being an important question.

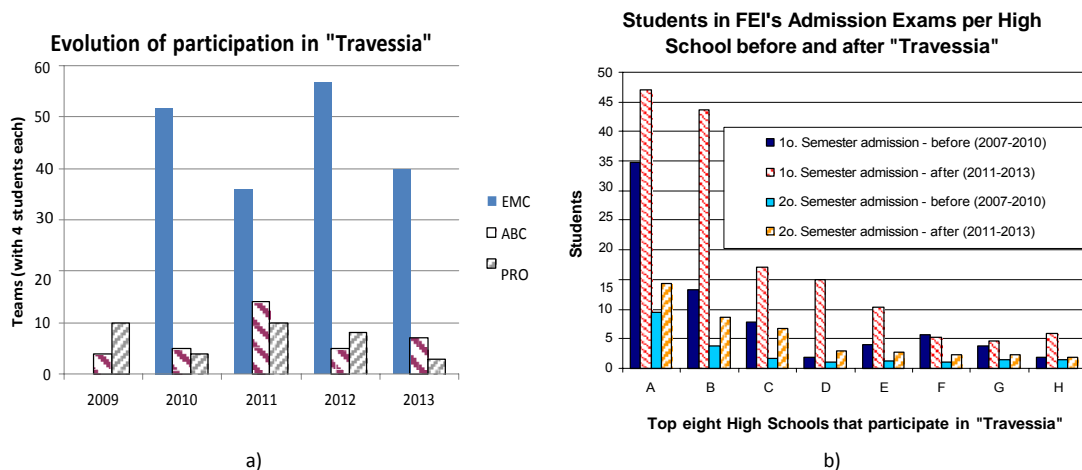


Figure 3: a) Number of teams per year and category; b) Rise of student's participation in FEI's admission exams

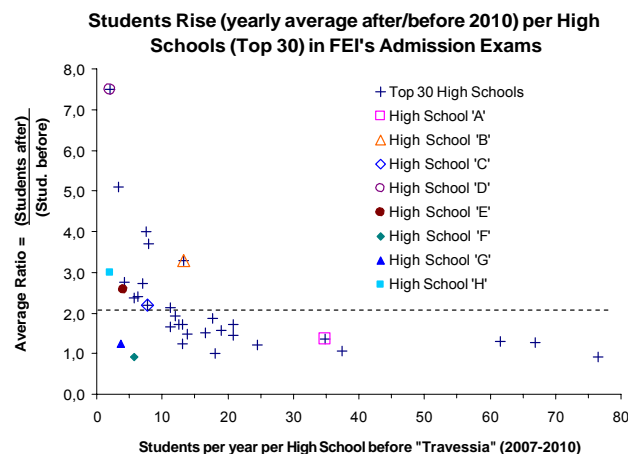


Figure 4: Comparison between the rises of student from contest's high schools and the other in FEI's admission exams

It's interesting to see in the figure 3b the rise in the student participation in FEI's admission exams before the contest (evaluating the 2007 to 2010 period) and after (2011 to 2013 period), to the top eight high schools that participate in "Travessia". The graphics separate the values of first and second semester of each year, because FEI has two exam dates, with different audience characteristics, showing generically that to all those high schools there was an increase in the number of students that participate in FEI's admission exams.

Trying to identify if this behavior was differentiated with respect to other schools, figure 4 shows a comparison between the top eight contest's high schools and the top thirty high schools participation in FEI's admission exams, before (2007-2010) and after (2011-2013) the contest began, noting that the first four contest's high schools are among those thirty. So, it can be seen that it is too early (little data to be analyzed) to be able to conclude anything, but three of those high schools have the rise ratio (after/before) bigger than the top thirty's average ratio.

Unfortunately, more data and analysis are necessary to assert that "Travessia" in fact attracts the students to engineering (particularly to FEI's courses), as, for example, a research with these students after their entering in a university. But it is clear that the students really enjoy the experience and grow after participating.

3 "COMPET" or "Platform to Develop Competitions about Structural Models with Recycled Materials", supported by CNPq

Drawing upon the experience with "Travessia's" proposal and organization, the author proposes a project to meet the "CNPQ-Vale Forma-Engineering" public notice, in which four high school students and an advisor teacher should develop a competition at their high school about structures with recyclables materials, being coordinated by a

university professor aided by an engineering student. The platform proposal envisages an Internet site creation, hosted on FEI's home page (www.fei.edu.br), in which the whole experience of building and running the competition was reported, to exchange experiences with other teachers of other high schools who want to deploy a similar proposal. The intention is to stimulate the high school students to be interested in engineering and experience the project, planning, building and testing a structure, and also that this experience itself be reproduced in other places.

In this case, the popsicle-stick bridge was not proposed because it was important that the students chose the theme and type of structure, thinking about their context and reality, especially because it was a public high school. This experience will be shown below.

3.1 Developing the theme and choosing materials

After the selection by the high school teacher, the four students had biweekly meetings with their teacher, FEI's professor and his engineering student to discuss about work methodology, structures behavior, other competitions around the world, kinds of recyclable materials and brainstorm to choose the structure. Some ideas were given and then discharged, as PET bridge or a catapult to launch anything. So, in a typical meeting, after watching a documentary about the ziggurats, as the Babel Tower would have been, the students proposed to build a one meter high PET bottle tower, named by them as "ComPET" competition. The PET bottles are a big environmental problem, also consumed by them and their colleagues, and so they were the chosen as the material to the tower. String of raw cotton and adhesive tape are included as bonding material, and some water could be used as counter weight.

3.2 Developing the tower test and the test equipment

Other meetings were needed to think about how to test the tower. As the tower should have stability, the decision was to test this property, pulling the tower to top until it leaned over or moved.



Figure 5: Building the tower (left) and test equipment (right)

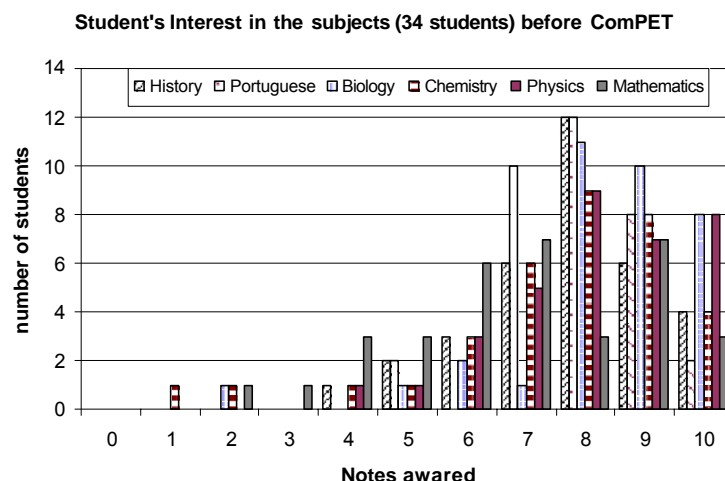


Figure 6: Student's interest in the subjects before ComPET

Figure 5 shows a team building the tower (left) and a view of the test equipment (right), improvised using a desk, a cardboard box and some balance weights. In this case, the available resources in the school were used, but a designed

equipment can be constructed to apply the loads. It's a big contrast with "Travessia", but it shows that it is possible to make proposals using few resources.

The students enjoyed the experience and after wrote reports about the behavior of the towers.

3.3 Analyzing feedbacks

In this proposal, questionnaires were applied, one before and another after the competition, to evaluate the eventual change of interest in engineering after participating in the competition. Later these results will be available, but, to anticipate some information, figure 6 shows students self evaluation about their interest in the subjects before "ComPET". Note that Physics is more popular than Mathematics (probably because is more applied), but both of them lost to History, Portuguese and Biology in this sample. The expectation is that something will change in the evaluation of the questionnaires that will be applied after the "ComPET". The experience was applied in two other high schools still in 2013 and will be related in future presentations.

4 CONCLUDING REMARKS

An interesting way to attract young talents to engineering is the competitions and contests in the high school, being another way of active learning, but rather being an experience to prove skills. It's very important that the contest theme be interesting to the students, and they should be challenged to give their best. The creativity must be stimulated and the organization committee should also have creativity to new proposals and changes to keep the contest attractive. It's interesting also promote the team's collaboration and to establish the skills to be developed in the contest, specifying them as goals to reach.

It's also important to have an evaluation form by questionnaires, or another way, and to interview the students after they choose their university careers to evaluate the effectiveness of the proposal, but is very difficult evaluate it in short time. Anyway, any proposal that stimulates the students to hands-on or active learning activities is rewarding because of the discoveries that the experience is able to provide.

Acknowledgment

The author thanks high school's directors and teacher Ricardo Pasin Caparrós for believing in the "ComPET" project. He also thanks FEI for encouraging and supporting the "Travessia" contest completion for the fifth consecutive year, to Telma de Jesus Cunha and her team for the survey data, and CNPq for the financial support to the "ComPET" project and for this paper's presentation.

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Using Active Learning to perform research in Engineering Education

The perceptions of engineering teachers on training in Project-Led Education: a case study

Samuel Ribeiro Tavares*, Luiz Carlos de Campos†

* Universidade Nove de Julho – UNINOVE – Rua Vergueiro, 235 – 01504-000 – São Paulo – SP – Brasil

† Pontifícia Universidade Católica de São Paulo – PUC-SP – Rua Marquês de Paranaguá, 111 – 01303-050 – São Paulo – SP – Brasil

Email: samueltavares@yahoo.com; lccampos@pucsp.br

Abstract

This paper offers a contribution to the theoretical foundations and practical applications of the PLE (Project-Led Education) methodology, which is still very incipient in Brazilian engineering schools, and requires more investigation on how and with what results it has been being used. Its purpose is to report the perceptions of eight teachers from one of the three universities studied by Tavares & Campos (2013), who underwent a training program designed on the basis of PLE methodology in order to better understand and apply that methodology. The training program was designed so that it allowed those teachers to experience the PLE methodology from their students' perspective. A synthesis of the teachers' perceptions about the training program, obtained through a Likert scale closed questionnaire, and confirmed through observation and unstructured interviews, indicated that a teachers' training based on the PLE methodology can be an effective way to help them understand and develop the new roles of teaching and learning in this modern educational approach.

Keywords: Engineering teaching and learning; problem-based learning; project-led education.

1 Introduction

In recent years, the expansion of higher education and the growing pressure from the productive sectors for qualified people have increased the need for a university that facilitates social and economic progress through knowledge generation and dissemination. Modern society demands the improvement of products and services, and expects the university to lead the technical and scientific development, ensuring its harmonious integration to the political and cultural context. Thus, the issue of the unitary school, which seeks to join the preparation of skilled labor to the market (professional education) with the formation of critical and conscious citizens (humanistic education), finally knocks at the doors of the university, which now must advance culture in order to fuel economic development (satisfying a technological demand) while making sure that the knowledge it produces and spreads can be used as an instrument against social injustices (meeting an ethical requirement).

In this scenario, slowly but steadily gaining awareness that modern human action is less related to doings and more connected to interventions, the university has been reviewing its relationship with knowledge.

Specifically in the engineering area, which now requires innovation through the creative adaption of knowledge to new contexts, it is becoming clear that the mere recollection of solved problems and the direct transfer of previously implemented procedures and solutions are not enough to cope with the challenging world. Modern engineering professionals are constantly faced with uncertainty, with partial information and competing demands, forcing them to acquire and develop not only technical skills but human relations competence too.

The PBL (Problem-Based Learning) and the PLE (Project-Led Education) methodologies are engineering programs' attempts to enable students to look for solutions to daily problems by means of a contextualized, dynamic and critical connection between theory and practice. The PBL methodology has been used to help learners adapt underlying theories to their individual cognitive structures through contextualized questions carefully designed to stimulate the students' critical and committed participation in finding explanations to authentic situations of the real world (BARRETT; MOORE, 2010).

In this methodology, as shown in Figure 1, inductive non-linear teaching and active learning have reportedly allowed students to tap into interdisciplinary knowledge (AMADOR *et al.*, 2006).

main features	PBL (problem-based learning)
expected results	students must provide explanations or suggestions to authentic situations of the real world
educational approach	a research model with emphasis on diagnosis on contextualized interdisciplinary knowledge
educational curriculum	educational curriculum is organized based on a problem with educational focus
educational design	analysis of the problem in large groups (ten or more members) looking for an answer for 1 or 2 weeks
theory-practice integration	students look for information in order to develop a hypothesis and offer an explanation or suggestion in class, when theory is finally elaborated
teachers' role	act as facilitators of students' doubts and as specialists in classes
students' role	analyze, discuss and generate tasks of learning from the proposed problem

Figure 1 – The main features of PBL methodology – Tavares & Campos (2013)

Unlike the small tasks and known answers to known problems that characterize the PBL methodology, the PLE methodology is focused on creating materials, artifacts, processes and systems with big tasks and multiple innovative solutions to challenging unknown problems (WEENK; van der BLIJ, 2011). The PLE methodology, as showed in Figure 2, adopts a hands-on educational approach, whereby students, while developing ideas and creating products strongly related to their future professional situations, identify, analyze and apply the most suitable theories to develop and manage their projects (POWELL; WEENK, 2003).

main features	PLE <i>(project-led education)</i>
expected results	students must develop new products (materials, artifacts, processes and systems) from a project theme according to the real world
educational approach	a production model with emphasis on practice based on the real world professional environment
educational curriculum	educational curriculum is organized based on support courses that help to implement a solution for proposed project with educational focus on the product
educational design	Working in small groups (maximum 8 members) students plan and develop their projects for 10 or more weeks
theory-practice integration	after elaborating on theories in classes, students devise and develop a product, while managing their projects
teachers' role	act as supervisors of students' projects and as specialists in classes
students' role	analyze, discuss, plan and generate an open solution from the project theme in order to create a product, process or system

Figure 2 – The main features of PLE – Tavares & Campos (2013)

However, although very promising, the theoretical foundations and practical applications of both methodologies are still very incipient in Brazilian engineering schools, and require much discussion about how and what results they have been being implemented in engineering programs. Tavares & Campos (2013) investigated how the PBL and the PLE methodologies have been used in the engineering programs of three Brazilian universities whose advertisements mention an investment in modern educational approaches.

They found out that while teachers believe that their actions are in the right path to the adequate implementation of the PLE methodology and their universities' attempts to revamp their educational approaches, their students hardly perceive their universities' intended proposals.

Informal talks with many of the teachers who took part in the research indicated that they (almost secretly) felt unable to implement the PBL and PLE methodologies' theory and practice in their classes. Among the possible reasons for this, two highlighted points were: 1) they had been educated within a traditional conception of learning; and 2) they did not really understand how the PBL and PLE methodologies work.

More than this, as students they had never been stimulated to acquire knowledge with own efforts, and they had always worked alone or in ill-formed groups. In face of this, they lacked the experience of critical thinking and problem solving, together with sharing common objectives and results, as it is required in PBL and PLE methodologies. So, as teachers, the concept of tutoring, supporting students' cognitive and social skills development, was almost alien to them.

In this paper, the authors describe an opportunity where teachers could experience the PBL/PLE proposal as students, in a context where they could become aware of the opportunities and difficulties of these methodologies' intense team work, strict timelines, real life problems and interdisciplinary knowledge.

According to Mills & Treagust (2003), the PLE methodology, with its concept of project management and product delivery, is more related to the engineering profession than the PBL methodology, and based on Tavares & Campos

(2013) research, which shows the PBL methodology as part of PLE methodology (Figure 3), a basic PLE methodology training program was designed.

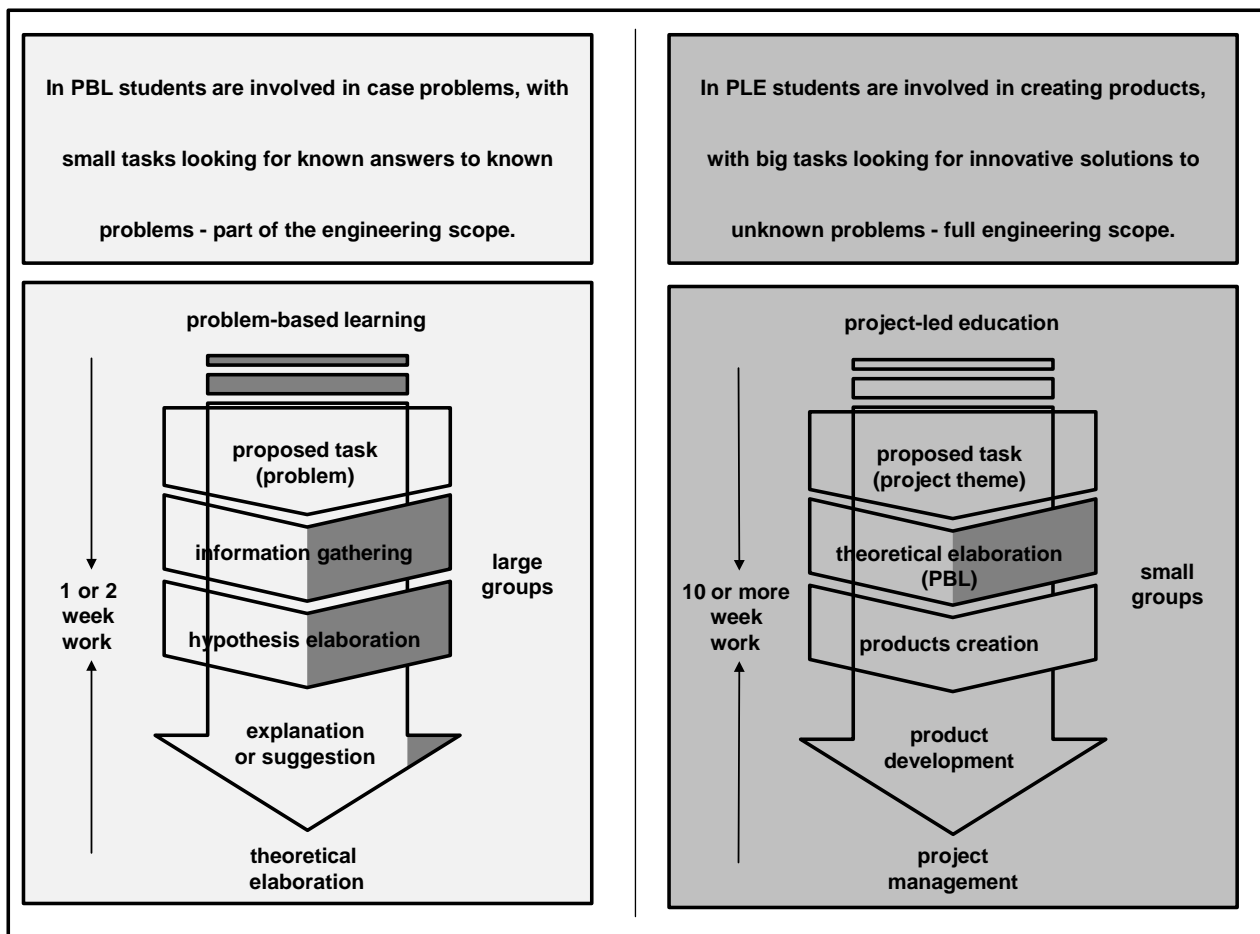


Figure 3 – The methodologies PBL and PLE in engineering courses – Tavares & Campos (2013)

The purpose of this paper is to report the effort of preparing eight teachers from one of the three universities studied by Tavares & Campos (2013) in order to take on their new roles in the PLE methodology, through a training program based on the PLE methodology, which would allow them to experience and practice of this new educational approach, and help them understand this challenge.

2 Methods

This study was carried out on the bases of the inductive method, which constructs or evaluates general propositions derived from specific examples, and of the observational method, which aims at accurately capturing the essential and accidental aspects of phenomena in the empirical context (FACHIN, 2005).

From among different techniques for data collection, this study relied on observation, unstructured interviews and a Likert scale closed questionnaire.

For the organization of the training program, the principles of Weenk *et al.* (2004) were followed, in a context where the engineering teachers were given the opportunity of experiencing PLE learning from their students' viewpoint.

The training program was carried out in five sessions with two hours each, whereby participants underwent teamwork project development and management, whose final result was the presentation of a conceptual model of PLE competences engineering teachers need.

3 Results

This section presents the organization of the training program, the conceptual model produced by the participating teachers and their perceptions on the task they developed.

3.1 Organization of the training program

Based on the principles of Weenk *et al.* (2004), Tavares acted as the tutor of 8 engineering teachers who took part in Tavares & Campos's research (2013) on how the PBL and the PLE methodologies were being implemented in the engineering programs of one of the three chosen Brazilian universities.

In the first session, the participating teachers started to share ideas and concepts for the completion of the task they should perform working as a team: the development of a conceptual model of PLE competencies in the engineering education.

In the second, third and fourth sessions, participants worked in an environment that resembled their students' classrooms, feeling the pressure to make decisions within a limited time frame, without the opportunity to discuss different points of view for extensive periods of time.

In the fifth and last session, the teachers, after presenting the most important features of their conceptual model, and discussing their proposal both in theoretical and practical terms, talked freely about their experience as PLE students, and answered a Likert scale closed questionnaire, handed out by the tutor.

3.2 Participants' perception on the training program

While discussing and negotiating roles and approaches concerning the development of a conceptual model of engineering teachers' necessary competencies in PLE, participants collected and analyzed data and information on the subject in a process which demanded cooperation and collaboration for the gradual construction of knowledge.

In order to better understand how this research's participants perceived this training experience, they were asked to answer a Likert scale closed questionnaire. Figure 4 shows a synthesis of the closed questions of questionnaire applied to teachers.

dimensions	1 = I totally disagree / 2 = I partially disagree / 3 = I partially agree / 4 = I totally agree	1	2	3	4
content integraton	Q01 In this training program, we had to search for, apply and integrate knowledge into our end product.				
	Q02 In this training program, we felt the need to take more responsibility for our learning.				
	Q03 In this training program, we were engaged in active learning, primarily self-directed.				
project management	Q04 In this training program, we had to plan, organize, direct and control our project.				
	Q05 In this training program, we felt the pressure to meet goals, time lines and budget expectations.				
	Q06 In this training program, we had to deal with interpersonal communication and conflict management.				
teamwok	Q07 In this training program, we had to exercise the communications skills of listening and speaking.				
	Q08 In this training program, we had to work cooperatively and exercise collaborative skills.				
	Q09 In this training program, we had to manage our own as well as our peers' performance.				
training program effectiveness	Q10 In this training program, we had the opportunity to experience engineering students' reality in PLE.				
	Q11 In this training program, we had the opportunity to visualize engineering teachers' challenges in PLE.				
	Q12 This training program increased our level of confidence to effectively implement the PLE methodology.				

Figure 4 – Basic structure of the closed question of the questionnaire

The questionnaire was structured in two parts in order to evaluate participants' perceptions on:

- 1) the conformity of the training program to the PLE methodology, which seeks to ensure content integration by means of project management carried out in teamwork (questions 01 to 09);
- 2) the effectiveness of a training program based on the PLE methodology in order to help teachers understand students' and teachers' roles in this new educational approach (questions 10 to 12).

4 Analysis

The analysis of the answers is presented in Table 1, which shows that:

- a) 70% of the participants totally agreed that the training program was designed to ensure the dimension of content integration (questions 1, 2, 3);
- b) 75% of the participants totally agreed that the training program was encompassed the dimension of project management (questions 4, 5, 6);
- c) 85% of the participants totally agreed that the teamwork dimension was an essential part of the training program (questions 7, 8, 9);
- d) 85% of the participants totally agreed that the training program effectiveness dimension was achieved (questions 10, 11, 12).

Table 1: Participants' perception on the task

TD = I totally disagree / PD = I partially disagree / PA = I partially agree / TA = I totally agree		TD	PD	PA	TA
1	In this training program, we had to search for, apply and integrate knowledge into our end product.	0%	15%	15%	70%
2	In this training program, we felt the need to take more responsibility for our learning.	0%	15%	15%	70%
3	In this training program, we were engaged in active learning, primarily self-directed.	0%	15%	15%	70%
4	In this training program, we had to plan, organize, direct and control our project.	0%	0%	25%	75%
5	In this training program, we felt the pressure to meet goals, time lines and budget expectations.	0%	0%	25%	75%
6	In this training program, we had to deal with interpersonal communication and conflict management.	0%	0%	25%	75%
7	In this training program, we had to exercise the communications skills of listening and speaking.	0%	0%	15%	85%
8	In this training program, we had to work cooperatively and exercise collaborative skills.	0%	0%	15%	85%
9	In this training program, we had to manage our own as well as our peers' performance.	0%	0%	15%	85%
10	In this training program, we had the opportunity to experience engineering students' reality in PLE.	0%	0%	15%	85%
11	In this training program, we had the opportunity to visualize engineering teachers' challenges in PLE.	0%	0%	15%	85%
12	This training program increased our level of confidence to effectively implement the PLE methodology.	0%	0%	15%	85%

5 Discussion

This paper reported the experience of preparing eight engineering teachers to take on their new roles in the PLE methodology, using a training program designed on this approach.

The synthesis on the participants' perception on the training program results, which was confirmed through observation and unstructured interviews, can be seen in Figure 5.

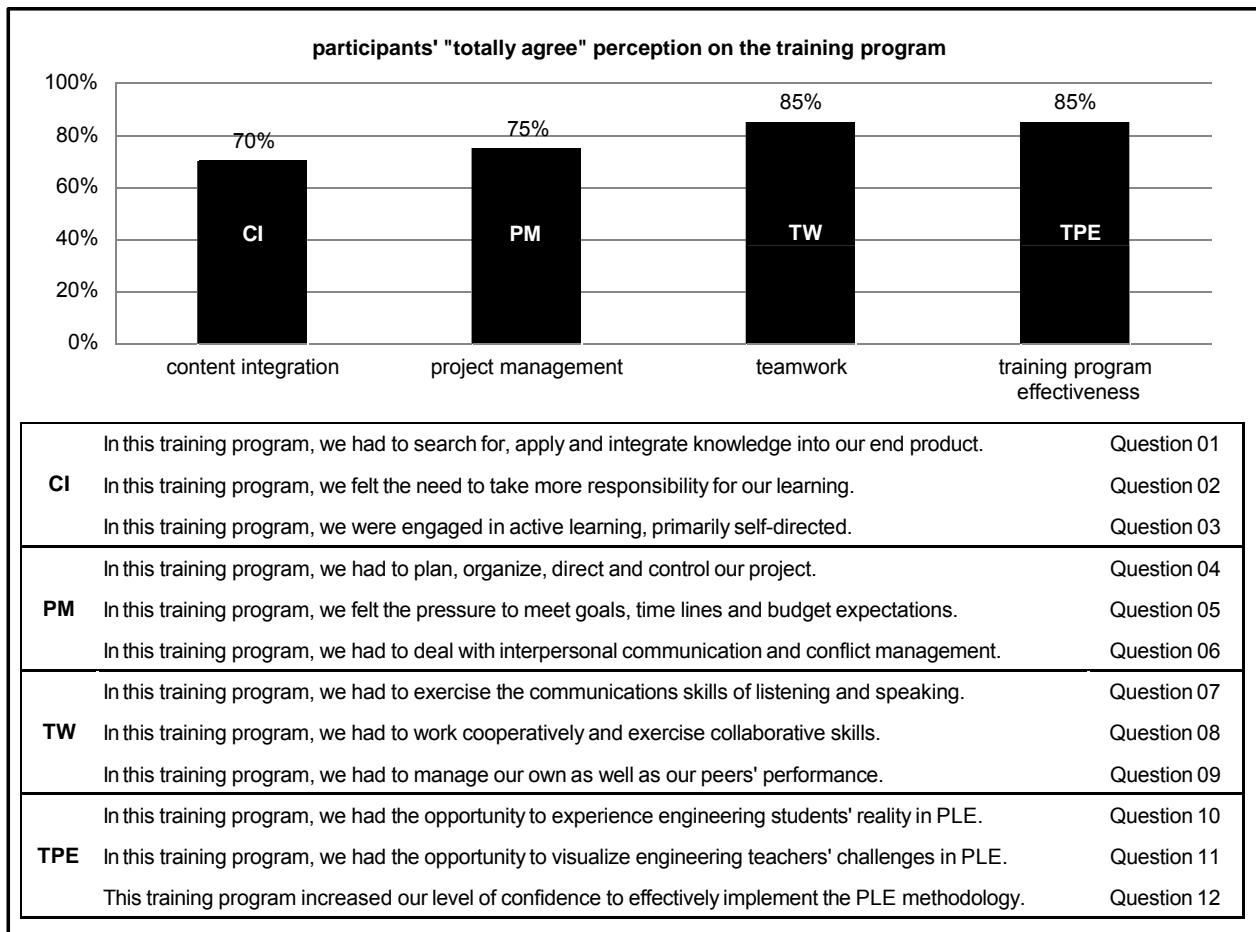


Figure 5 – Synthesis of participants' perceptions on the training program

Based on the results, it is possible to conclude that engineering teachers' trainings based on the PLE methodology must be seen by engineering schools as a contribution to an effective understanding and development of the new roles of teaching and learning in this modern educational approach. All those who are involved with the teaching and learning of engineering education must be prepared for this new stage.

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Theoretical Framework of Problem and Project based Learning in Engineering Education

Gabriela Ribeiro Peixoto Rezende Pinto^{*}, Octavio Mattasoglio Neto^{*}

^{*}Universidade Estadual de Feira de Santana, Bahia, Brasil

^{*}Centro Universitário do Instituto Mauá de Tecnologia, São Caetano do Sul, Brasil

Email: gabrielaprp@gmail.com, omattasoglio@maua.br

Abstract

This paper presents the results of a Session Addressed about theoretical framework of Problem Based Learning and Project Based Learning. This meeting was carried out in an Engineering Education Congress in Brazil and, from registration of papers on the topic, the discussion was guided by questions that served as "catalysts" of the main topics to be discussed. The results show the theoretical references for both the Problem Based Learning as for Project Based Learning are used to justify the main ideas of these strategies. Furthermore, it was possible to know that there is a need for help from professionals of education area to, together with engineer, build the effective knowledge with the use of these strategies.

Keywords: problem based learning; project based learning; symposium information; project approaches.

1 Introduction

The teacher's lab is the classroom, is there where perform experiences to improve the efficiency ratio in teaching-learning. As in other types of experiments, the researcher, and in this case the teacher, has the need to share the results founded with their community, in order to show what it have been done and indicate the path to ensure the reproducibility of the experiment and otherwise avoid unsuccessful experiments.

The reported experiments follow rule and regulations, to ensure a cumulative and consistent evolution of science. Thus, the collect data should use appropriate techniques, consistent with the adequate to the analysis to be held. In addition, research must still have their boundary clearly defined, to guarantee the generalization of results to similar cases. Furthermore, the goals of a research must be precisely determined, translated in a question that dominates the thinking of the researcher along the way, and motivate, up to the end of the experiment (Marconi and Lakatos, 2010).

There is still another important support of a research, which is the prior knowledge on the subject, built by researchers who pored over the problem, seeking understands it. This prior knowledge is often constructed from knowledge of other areas, for example, education makes use of knowledge from sociology, psychology and others, establishing metaphors that facilitate understanding of classroom phenomena. So, when a new research is being done, the ideas and the results from others researchers are a benchmark from which the teacher will conduct its analysis. This theoretical framework will also determine the boundary condition, and allow different researchers talk about various experiences, using a base language enabling a evolution in area.

Like another areas, in engineering education it is common to find reported experiments with a theoretical framework, but sometimes there aren't a strong link between this referencial and experiment, with weak mediation between them. An experiment must go beyond to report how it was conducted and what were the results, but should ensure a dialogue between the results and what the theoretical references and discuss the suitability and limitations of theoretical references, from new data, and even encourage to change the theory borders .

The question that arises here is: Which are theoretical references that are being used in engineering education, by Brazilian researchers? More precisely, the question is: Which theoretical references are used when discussing the Problem Based Learning - PBL and Project Based Learning PjBL engineering in Brazil? This question is importante, because just It's possible to progress in the implementation of PBL or PjBL strategies, with evidence that put boundaries delimiting the discussion, ie, the theoretical framework from which to confirm or deny certain results or, on the other hand, if the results of experiments, put in check or extend the references's border. In the extreme case can even deny the references like inadequate to be reference to the strategy of PBL and PjBL.

It is necessary to define the acronyms used to the strategies that will be discussed here. Problem Based Learning is indicated by PBL. Strategies that use learning by project are indicated by some authors for Project Led Education,

PLE, or by Project Oriented Learning, POL. The choice in this paper is to indicate these strategies by Project Based Learning, PjBL. For reference the Session Addressed - will be used the acronym SD. A SD is an event promoted by the Brazilian Congress on Engineering Education (COBENGE), who is a location for presentation, discussion and articulation of academic work, gathering researchers and interested by a specific theme.

Reports the classroom's experiences is a good thing, but from now it's important go beyond. The result of two SDs performed in previous issues of COBENGE - 2011/2012 - highlighted the need to evolution in search of references more consistent and, consequently, a fruitful discussion about the PBL and PjBL. In an independent and autonomous, two SDs were proposed in 2013 to identify the theoretical references for the work done on Engineering Education, the first one on PBL and another on Active Learning. It means that more researchers are motivated to find and reinforce the discussion and thought over theoretical on learning in engineering. The number of participants on these SDs shows that PBL - Problem or Project - are strategies that have attracted increasingly teachers, pointing that a growing number of institutions are sensitive to promote active learning strategies.

Epistemology is the concept which defines the genesis and development of knowledge in engineering. From the knowledge of theoretical framework, maybe it's possible to know the origin of knowledge in engineering. If PBL and PjBL are strategies that approximate of strategies used by engineers in their work, it's possible to believe that the identification of this kind of thinking from the theoretical frameworks can help understanding what is and how develop the engineering's knowledge. Basically, the questions are: What makes a person an engineer? If PBL and PjBL are strategies aligned with engineering, these can lead us to understand what become a person an engineer?

The objective of this work is to identify theoretical references guiding the practice of PBL and PjBL in engineering courses in Brazil. From the experiences of several researchers in engineering education, we are trying to trail the path that is used to support the work with PBL in engineering. It's an unpretentious goal, but for the team who participated of SD, is an essential work.

2 Methodology

In the 2013 edition of COBENGE, held in Gramado¹, In the 2013 edition of COBENGE, held in Gramado, the authors of this article proposed a SD entitled "Theoretical Foundations of Problem Based Learning Strategies and Project Based Learning Experiences in Engineering Education ", which was approved and has been implemented in three steps: Step 1 - Preparing the SD (already done) Step 2 - Discussions face (already done) and Step 3 - Writing a book chapter (in process).

Step 1 - Preparing SD - The proposal of SD was submitted and aproved by COBENGE's committee, then was done a call for papers. The papers received were evaluated and those selected have been organized to compose the final paper with the contribution of all those works. The following works were selected:

- Problem-based learning - Theoretical Basis for practical study in Civil Engineering, by Renato Martins das Neves, of Federal University of Pará. This work explains the origin of the PBL, its relationship with the theories of Jerome Bruner, John Dewey and the constructivism theory, their bases, how is the learning organization from the PBL and some challenges related to its application.
- A simplified theoretical framework for understanding the PBL and PLE approaches in education in Engineering by Samuel Ribeiro Tavares and Luiz Carlos Campos, the UNINOVE and PUCSP respectively. This work argues that experiences with approaches PBL (Problem-Based Learning) and PLE (Project-Led Education) on engineering courses have increased in recent years, and the results seem better than other strategies in use. The authors also show a comparing table such strategies using the Bloom's taxonomy and Kolb's learning cycle.
- A Methodology of Meaningful Learning, Applied to solve Oxidation-Reduction problems, by Ivete Ana Schmitz Booth, Ana Maria Coulon Grisa e Rosamary Nichele Brandalise, of da Universidade de Caxias do Sul. This work associated the PBL with the theory of Ausubel's meaningful learning. It shows an experience of the application of PBL in chemistry's course with problems related to redox.
- Theoretical Foundations of PBL Guiding Planning Workshops for High School Students, by Isolda Grani de Lima, Ivete Ana Schmitz Booth, Laurete Zanol Sauer e Valquíria Villas-Boas, da Universidade de Caxias do sul. This work shows how the fundamentals of PBL are used to motivate learning of high school students. The experience is linked to UCSPROMOPETRO project: New Challenges for the Future Engineer (PETROFUT), developed at the University of Caxias do Sul, whose main purpose is to strengthen the teaching of science and awaken young people's interest in engineering career.

¹ The theme of COBENGE 2013 was "Engineering Education in the Knowledge Age"

- Engineering Education in the Information Society, Active Learning Strategies and Experiences Published in COBENGE, by John Alberto Castelo Branco Oliveira, Gabriela Peixoto Rezende Ribeiro Pinto and Jessica Magally de Jesus Santos, State University of Feira de Santana. This work presents how the PBL is being expanded Engineering courses in Brazil and shows, from the time of the experiments reported in the Annals of COBENGE, from 2008 until 2012, the main theoretical references cited by the researchers.

Step 2 - Discussion in SD - Happened during the face to face meeting at COBENGE - September 2013, attended by the coordinator, the rapporteur, the authors of articles and sixty-six representatives from several universities in Brazil, many of whom actively collaborated in the discussion. Initially happen a presentation of papers by the authors, then a collective discussion about the content of the papers. These discussions were led by the following questions:

1. What is understood as theoretical foundation of educational method?
2. What are the differences between Problem Based Learning and Project Based Learning?
3. What theoretical foundations are related to Problem Based Learning and Project Based Learning in Engineering Education in Brazil?
4. As these theories objectively influence the current pedagogical practices that make use of active learning strategies? Which indicators are identified from the discussions about the use of PBL and PjBL and also the theoretical foundations rose?
5. Examples of application of PBL and PjBL in elementary education, secondary and higher and its relation to the theoretical foundations.

To ensure the memory of the discussions asked the participants to consent that the discussions were recorded, which was done. Some of the lines are presented in the article, but to ensure the anonymity of the authors, we chose to mention them using the identification Participant, (random number) - SD4, (COBENGE2013).

Finally, in Step 3 - Writing a book chapter Is under construction. The result is a book chapter collectively produced, which is based on the papers submitted and the contributions of the main ideas that emerge from the discussion that occurred along the SD.

This article is an essay on the reflections obtained from reading the articles, the presentation of papers and discussions that took place at the event (the transcription of audio produced was relevant to the survey categories of analysis - indicators). For its preparation, the authors relied on a method called content analysis of Bardin (1987, p. 30), which seeks to "examine the contents of communications beyond its immediate meaning."

3. Theoretical foundations and its relationship with the PBL and PLE

In this section it is presented the production of knowledge obtained from research and collective reflections made about the guiding questions: 3.1. What is meant as theoretical foundations of an educational method? 3.2 What is PBL PjBL and their differences? 3.3 What theoretical foundations are related to the practices of Problem Based Learning and Project Based Learning? 3.4 Application's example of PBL and PjBL at fundamental, secondary and higher education, and his relationship with the theoretical foundations.

3.1 What is understood as theoretical foundation of educational method?

To choice of a teaching strategy means making an option for an epistemological conception and belief that the student builds their knowledge of a particular way. When make a choice the teacher believe that it's the most fertile way to promote learning. One strategy might be choosed by teacher's experience, who identified its effectiveness in practice but without link to any learning theory, which can be by lack of any knowledge about learning theory, or poor contact with these theories. On the other hand the options are linked to known theories of learning, already studied, by other researchers, and admittedly fertile to promote learning. The connection between a theoretical framework and practical teaching should not make such limited practice, instead should be a guide and, for his scientific feature, allows test it and verify its limits. The teaching activities must have the character of science research and not the unquestioning belief in the principles that have rigid boundaries only by virtue of the will of his mentors. Thus, what learning is, and link this idea with a specific author or theory is desirable to carrying out the teaching work, ensuring the dialogue about this practice and overcoming the common sense about it.

At this point an option is taken: Not is any theory that meets the needs for the implementation of strategies such PBL and PjBL. The option is for those that accept that "learn is actually build your knowledge, with the main actor [the student] who will build your knowledge. ... Theories that profess learning for life, meaningful learning, non-mechanical", Participant65SD4 (COBENGE 2013). Above all, it is need to admit that each one learns of his way, not like the others.

Learning is understood as indicated by Anthony (1996):

- ... a process of knowledge construction, not of knowledge or absorption;
- ... is knowledge-dependent; people use current knowledge to construct new knowledge;
- The learner is aware of the processes of cognition and can control and regulate them; this self-awareness, or metacognition (FLAVELL, 1976) significantly influences the course of learning.

In turn, metacognition means the process of reflection and learning control exercised by the student (Gunstone, 1991). For this author, it is a personal, aware and complementary process to the construction of knowledge, and a way for the learner to control their own knowledge and to promote conceptual change when facing difficulties in certain aspects other than cognitive. Hewson and Hennessey (1992) use a next procedure of metacognition in monitoring the status that students take concepts throughout a course.

The linking to the theory should be explained, so the teacher might read what are doing, identify which dimensions must be considered in your practice and what value they assign for them. By this knowledge is that the teacher will evaluate your work and share their findings with the community.

A theory must allow a more general understanding about learning, an indication of which strategies are aligned with it, indicate the dimensions and tools of evaluation, flexibly but respecting its principles.

Such concerns regarding the methodological rigor of approach, refers to Bardin (1987) expressing his defense by a methodological rigor when comes to content analysis:

Appeal to these instruments of laborious investigation documents is situated beside those, from Durkheim to P. Bourdieu through Bachelard, want to say no <<illusion of transparency>> of social facts, refusing or trying to ward off the dangers of spontaneous understanding. It is equally <<become suspicious >> relatively at assumptions, to fight against the evidence of knowledge subjective, destroy intuition in favor of << built >>, reject the lure of naive sociology, which believes he can intuitively grasp the significance of the protagonists social, but that only affects the projection of his own subjectivity. This attitude of critical vigilance << >> requires methodological diversion and use of << break techniques >> and it is much more useful to the specialist humanities, the more he has always a familiarity impression of their object analysis. It still say no <<to reading simple of reality>>, always seductive, forging operational concepts, accept the provisional nature of hypotheses, define experimental or research plans (in order to foil the first impressions, like say PH Lazarsfeld).

This without falling into the trap that (of game): build to build, apply the technique to assert good conscience, succumb to the magic of methodological tools, forgetting the reason for its use (Bardin, 1987, p. 30).

3.2 Problem Based Learning

3.2.1 What is PBL?

Frost (1996, cited in NEVES, 2013) "argues that PBL evolved from dissatisfaction with the results of the traditional curriculum and teaching methods used in the training of medical students." For the author, "during the 50s and 60s, the courses were focused in content (subject-centered) and class (lecture-centered)." This situation translated into teaching strategies that had little use for effective practice of professional future.

As an alternative to traditional methods, PBL enters the training scenario in Medicine and emphasizes:

"The development of essential skills such as effective analysis of the problem (BARROWS; TAMBLYN, 1976; WOODS, 1996; ENGEL, 1997) and self-study directed. The student-centered approach also develops the ability to listen, summarize information and the ability to teach others (BARROWS; TAMBLYN, 1976). Teaching peers is a skill required by most professionals, along with the ability to work as part of a team (BARROWS; TAMBLYN, 1976; WOODS, 1996). Interpersonal skills are obtained through questioning of colleagues in a collaborative way. This process also enables students to change (WOODS, 1996; ENGEL, 1997) and critical thinking skills (ENGEL, 1997). In addition to these skills, Woods (1996) points out: the learning for lifelong, the self-directed learning and the self-assessment. Students themselves participate in the assessment of these skills. In fact, this creates a dilemma, only students develop these skills if they are able to avail the maximum the PBL. This approach deals the learning content in the context of the use and development of technical and of skills. (Neves, 2013)

The principles that support PBL are (SCHMIDT, 1983; DAVID; PATEL, 1995): Activation Prior Knowledge; Knowledge elaboration; Learning in context; Transfer of principles and concepts; intrinsic interest; Learning for life (NEVES, 2013).

PBL is a student-centered strategy, which aims at learning in the context of real, complex and multifaceted problems (GRAAFF and KOLMOS, 2007). Presupposes teamwork, identification of previous knowledge, which is necessary to know, and how and where to access new information that could lead to solving the problem (Villas-Boas et al, 2011). The teacher's role is to facilitate learning, develop an appropriate structure of the process by probing

questions, provide appropriate resources, lead class discussions, and to evaluate the students. The objective is to enhance the development of essential skills for student success, both in public and private domains.

PBL seems to become an effective strategy because it joins with cognition and metacognition with subjective aspects, which can hold learning in engineering (Anthony, 1996).

Pintrich, Marx and Boyle (1993) have criticized the extremely rational character of some teaching approaches, raising questions about learning science, which can extend to engineering, as associated with strictly rational aspects. For them, motivational factors and cognition are closely linked. Consider that the classroom environment can also influence learning.

"This strategy of just-cognition is useful to investigate the general cognitive ability of the individuals in an experimental situation where their problems or tasks with relatively clearly defined are given, but the model loses some usefulness when applied to students engaged in academic tasks in the classroom. And students may adopt different objectives and proposals for their school work, and engage cognitively in a myriad of tasks classroom is really a choice that they have to do alone. Moreover, the level of engagement and want to persist in a task may be a function of motivational beliefs. "(Pintrich, Marx and Boyle, 1993).

3.2.2 What are the differences from the PLE?

Table 1 (TAVARES and CAMPOS, 2013) compares the two approaches applied in engineering courses as their implementation aspects of educational objectives and expected results. Experiments using PBL coexist with other strategies and contribute to the development of both, technical skills as collaborative problem solving to technology development and innovation for generating.

TABLE 1 - PBL and PLE courses in Engineering.

Dimensions	pbl – Problem based learning	ple – Project led education
Outcomes	It is expected that Students offer explanations or suggestions to authentic real-world situations.	It's expected that students create new materials, devices, process and systems to a world in change.
Educational approach	Conceived as research model, emphasizing the analyse and interdisciplinary contextualization of knowledge.	Conceived as production model, with emphasis on practice in a real professional context.
Curricular structure	Curriculum organized based upon the proposition of issues, focusing on the process.	Curriculum organized base upon proposition of tasks, focusing on the product.
Didactic action	After presentation of the question, teams with over 10 students, seek answers over 1 or 2 weeks.	After presentation of the task, teams with over 10 students seeks develop the Project, over 10 or more weeks.
Integration of theory and practice	Students collect information to share hypotesis and/or sugestions in class, when the theory is elaborated.	While seeking information, students develop a project, identifying / creating theories and managing resources.
Role of teachers	Act in the classroom, as facilitators in the research of students and specialists.	Act in the classroom as supervisors of student projects and specialists
Role of Students	Define and conduct research about the question, to propose hypotheses and / or suggestions.	Define and conduct research on the topic for product development.
Overview	Students study cases with small tasks that include questions and known solutions.	Students create products with great tasks that lead to innovative solutions to unknown issues.

Source: Tavares e Campos (2013)

Tavares and Campos (2013) argue that these strategies are encouraging, but agree on the need for discussion and exchange of experiences in using these approaches in order to consolidate its theoretical foundation and its mode of application, which makes need relevant conduct studies on its use and results in Engineering courses in which they are applied.

In summary, since there is demand for technical and ethics for effective ways of teaching and learning engineering, it is necessary to invest in research aimed at the discovery and application of new processes and educational approaches that go beyond the mere transmission and accumulation of data, and promote information sharing and creation of knowledge, combining theory and practice in the training of engineers pragmatic (able to

identify, model and solve problems) and cooperative (able to work in multidisciplinary teams) (TAVARES e CAMPOS, 2013).

3.3 What theoretical foundations are related to the practices of Problem Based Learning and Project Based Learning in COBENGE community?

The need for problem solving or the need for project development is part of day-to-day engineer. Consequently, having a didactic action whose motto is problem solving or development projects, is something that should come as something natural in teaching practice in engineering. Many teachers realize this and, in a more or less organized way, bring this strategy to the classroom. Sometimes it happens empirically, without a clear perception of theoretical structure and, in some cases, based on experiences and reflections on practice based on educational theories.

After reviewing the references of each article on the PBL obtained from the annals of COBENGE (2008-2012), performed by Oliveira et al. (2013), it can be seen that two researchers addressing PBL are very cited: Howard S. Barrows, who is researching PBL in the context of medicine and Luiz Ribeiro, Brazilian researcher which relates to engineering education. Tables 1 and 2 present the papers that were cited by these authors.

Table 1 – Most cited researcher in international items COBENGE.

Papers issued by Howard S. Barrows.
BARROWS, H.S. and TAMBLYN, R.M. Problem-based learning: an approach to medical education. New York: Springer, 1980.
BARROWS, H. S.; KELSON, A. M. Problem-based Learning: a total approach to education. Monograph. Southern Illinois University School of Medicine, Springfield, Illinois, 1993.
BARROWS, H. S. Problem-based learning in medicine and beyond: a brief overview. In: WILKERSON, L.; GIJSELAERS, W. H. (Eds.). Bringing problem-based learning to higher education: theory and practice. San Francisco: Jossey-Bass, 1996. p. 3-12.

Table 2 – Most cited researcher in national items COBENGE.

Papers issued by Luiz R. de C. Ribeiro
RIBEIRO, L. R., MIZUKAMI, M.G.N., A PBL na Universidade de Newcastle: Um Modelo para o Ensino de Engenharia no Brasil? Olhar de Professor . Ano/vol 7, no 001, Universidade Estadual de Ponta Grossa, Ponta Grossa, Brasil, pp 133-146, 2004.
RIBEIRO, L.R.C.; ESCRIVÃO FILHO, E.; MIZUKAMI, M.G.N. Uma experiência com a PBL no ensino de engenharia sob a ótica dos alunos . Revista de Ensino de Engenharia, v.23, n.1, p. 63-17, 2004. Monografias, dissertações e teses:
RIBEIRO, L. R. de C. A Aprendizagem Baseada Em Problemas (PBL): Uma Implementação na Educação em Engenharia na Voz dos Atores . Tese de Doutorado. Universidade Federal de São Carlos, 236 p., 2005a.
RIBEIRO, L.R.C.; MIZUKAMI, M.G.N. <i>Student Assessment of a Problem-Based Learning Experiment in Civil Engineering Education</i> . Journal of Professional Issues in Engineering Education and Practice. p. 13-18. 2005b.
RIBEIRO, L. R. C. Radiografia de uma aula de engenharia . São Carlos: EDUFSCar, 2007.
RIBEIRO, L. R. C.; ESCRIVÃO FILHO, E. Um sistema de avaliação no ensino de engenharia: A visão dos alunos em uma experiência com o PBL . In: XXXV Congresso Brasileiro de Educação em Engenharia. Curitiba PR.. Anais. COBENGE 2007, Curitiba: UNICENP, 2007. CD-ROM.
RIBEIRO, L. R. C. Aprendizagem Baseada em Problemas (PBL): uma experiência no ensino superior . São Carlos: EdUFSCar, 2008.
RIBEIRO, L. R. D. C. Aprendizagem Baseada em Problemas (PBL) na Educação em Engenharia . Revista de Ensino de Engenharia, 27(2), 23-32, 2008.
FILHO, E. E.; RIBEIRO, L.R.C. Aprendendo com o PBL - Aprendizagem baseada em problemas: relato de uma experiência em cursos de engenharia da EESC – USP . Revista Minerva, São Carlos, v.6, n.1, p. 23-30, 2009.

On the foundations of PBL, Ribeiro (2005b) explains that some theories have been cited as potential influencers for its constitution, for example, the theories of Jerome Bruner, John Dewey, Piaget, Ausubel, Freire and Rogers. Moreover, when it addresses the fundamentals of PBL, cites the study by two researchers from Brazil, and Mamed and Penaforte (2001), cited in the area of health. These authors present their work in a comprehensive study of the fundamentals of PBL, referring to the theories of the philosopher John Dewey and of psychologist Jerome Bruner as likely influencers of the initiative.

From Ribeiro (2005b), and Mamed and Penaforte (2001) and Moreira (1999), Oliveira et al. (2013) identify, from the papers presented at COBENGE in the period 2008-2012, the theoretical knowledge, teaching and learning most cited, as shown in Table 3.

Table 3 – Theorists cited in the articles of COBENGE.

Theorists associated with PBL	Origin	Theory
AUSUBEL, D. P. A aprendizagem significativa : a teoria de David Ausubel. São Paulo: Moraes, 1982.	Medicine Psychology	Theory of Meaningful Learning of Ausubel
BRUNER, J. <i>The culture of education</i> . Cambridge, MAS: Harvard University Press, 1996.	Psychology	Theory of Education
DEWEY, J. <i>How we think</i> . Lexington: D. C. Heath Co., 1933.	Philosophy	Theory of Knowledge
FREIRE, P. Pedagogia do oprimido . Rio de Janeiro: Paz e Terra, 2005.	Pedagogy	Theory of Critical Pedagogy
KELLY, G. A. <i>The psychology of Personal Constructs</i> . Norton: New York, 1955.	Mathematics e Physics Educational Sociology Psychology	Psychology of Personal Constructs
PIAGET, J. Abstração Reflexionante . Porto Alegre: Ed. Artes Médicas, 1995. PIAGET, J. Fazer e compreender . São Paulo: Melhoramentos, Edusp, 1978.	Psychology	Theory of Cognitive Development
VIGOTSKY, L. S. A formação social da mente . São Paulo: Martins Fontes, 2003.	Advocacy Literature Psychology Medicine	Theory of Mediation

Source: Oliveira et al (2013).

3.4 Examples of application of PBL and PjBL in elementary education, and higher, and his relationship with the theoretical.

During SD and discussions of proposed questions coming, it was confirmed that the authors raised by Oliveira et al. (2013) are related to experiences with PBL in engineering education in Brazil. Neves (2013) related the PBL to the theories of John Dewey and Jerome Brunner and also mentioned their relationship with cognitive theories (Piaget and Vygotsky), Booth et al. (2013) in his research related to the PBL significant Ausubel theory. Tavares and Campos (2013) chose to analyze the PBL and PLE based on two authors who did not appear in Table 1: Bloom and Kolb. Finally, Vilas-Boas et al. (2013) relate their experiments guidelines Luiz Ribeiro.

The simplicity of the ideas about education and proximity to solve real problems were the attractions for the approach to a theory (Dewey, 1959), which became the basis for the experiment conducted by Participant 59SD4 (COBENGE 2013), which identified "that [Dewey] had to do with the world of the engineer". Another element that promotes approach to learning theories is the need for interpretation of the subject as an agent that learns this process. In this case, Ausubel (1982 and 2003) and Piaget (1978) become a reference for this interpretation.

Ausubel (1982 and 2003) is also a reference when the subject is the "labor management intervention" Participant 26SD4 (COBENGE 2013) and, more specifically, to address the dynamics of previous organizers as link elements for the realization of teacher's interventions collaborating in knowledge reconstruction. In this case, insert discussion about the role of the teacher, relating appropriately the size of the challenges in order to bring the student to want to be part of the learning process, ie, to engage in tasks and produce meanings. Participant 26SD4 (COBENGE 2013), the theory of Ausubel focuses this construction of meaning through this interaction of student tasks, challenges, problems.

Participant 38SD4 (COBENGE 2013) que declares the PBL is linked to constructivism, the way you organize student work, linked to the object of Promoting learning and social interaction, mediated by the teacher.

PBL, the flexibility with which it should be treated, leads to thinking about complex that come Edgar Morin (2006). According to Participant 20SD4 (COBENGE 2013), Morin (2006) points out the need to leave this place where you are and move toward other references for the interpretation of the phenomenon of learning. By location can have many different interpretations, for example, leave the area of cognitive and thinking that the humanities social sciences, and even subjective emotional side is as important as essential as the objective side, to interpret the learning process.

Also according to Participant 20SD4 (COBENGE 2013), we highlight two Brazilian authors remembered, not by designing a theory of learning, but they did for the synthesis of the experiences of Problem Based Learning, and the redemption of the origins of thought on this topic. The first was Ribeiro (2004 and 2007) and other Penaforte (2011), who discussed the PBL in engineering and health sciences, respectively. For these authors, there is something that generated the PBL, but two main sources are John Dewey, the area of philosophy that deals with the theory of knowledge, and Jerome Bruner, a psychologist and who has a theory of teaching. Carl Rogers was also remembered as connected to the humanist epistemological current. All these factors indicate the complexity and need for knowledge, for example, conflict management, since subjective aspects of the lives of those involved in the process are there, and this interferes with reason and learning.

Not to forget to mention all the contributions that have emerged in SD, it should be pointed out that besides these thinkers linked to psychology, philosophy and epistemology, neuroscience has also been cited as a tool for understanding the phenomena of learning Participant 35SD4 (COBENGE 2013) why is it that one can have an understanding of the origin of the phenomenon of learning and how this learning that works more significantly.

4. Initial reflections on the relationship between theoretical foundations and practices of PBL

In this section we present the production of knowledge gained from research and collective reflections made on the guiding question 4.1. How these theories objectively affect the current pedagogical practices, which has been making use of active learning strategies? I.e indicators that can be lifted from the collective reflections on practices and PjBL with PBL and the theoretical foundations raised?

4.1 What indicators can be lifted from the collective reflections on practices with PBL and PjBL and on the theoretical foundations raised?

From the analysis of the transcripts of the audio recorded on SD, and based on some guidelines Bardin (1987) on content analysis, the following indicators were identified from the collective reflection on practices with PBL and PjBL and theoretical foundations associated. Were collected and analyzed: 4.1.1 Theoretical framework should not determine the details of the action of the teacher in the classroom; 4.1.2 Need to rethink the assessment of student performance in PBL and PjBL; 4.1.3 Need for partnership with education professionals for implementation and assessment of the implementation of PBL and PjBL; 4.1.4 Need for training teachers to work with PBL and PjBL and 4.1.5 Some conditions required for the teacher to work with PBL and PjBL.

4.1.1 Theoretical framework should guide, not determine the actions of the teacher in the classroom

A theoretical framework should not mean a limitation in teaching, by strictly following the guidelines, it is understood, are implications of this framework. Should not require a theoretical framework indicate details of how the teacher should conduct your experience in the teaching-learning process. Follow details in the implementation of a strategy for teaching work, as the form of organization of students in the classroom, the rating form, the form of presentation of content, approaching the work in the teaching learning technique in which fine rules must be followed, and if they are not, to discard a given strategy. That is not what is meant by theoretical foundation for the conduct of work in the classroom.

Some teachers feel the need of techniques or, more precisely, to work with the PBL and PjBL Participant1SD4 (COBENGE2013). Apply these strategies is not simple, requiring the knowledge and supervision of experienced people with their application, which can collaborate in the implementation. Another possibility is the implementation of humanistic disciplines, collaborating to think about issues of human relationship. But, as highlighted Participant2SD4 (COBENGE2013), the implementation must be conducted as a network, with the collective and flexibly.

The teacher has a feeling about conducting their experiences in the classroom, usually based on what he reads, what absorbs some theoretical foundation, although often not fully aware of its action linking to these references. The teacher believes in what you're doing, then, is not randomly taking decisions. Thus, details such as the number of components of a team of students to develop a project, or how they will ensure the interaction between work teams, or even the exchange of components within a work team, are details that can and should be evaluated by the teacher, based on the verification of student learning, the relationship between the students on the team, the fulfillment of tasks, finally considering all dimensions of learning, knowledge, skills and attitudes relevant to the formation of engineer.

Each teacher works according to his conception, establishing rules beforehand, that originate, even the experience as a student throughout their training process. These rules aim to cover all this theoretical foundation of educational principles in which believes.

The process of teaching and learning in school life has a key feature that is the intention, this leads to the requirement for reasons to run. Such reasoning will indicate planning and organization. Strategies such as PBL and PjBL require that reasoning, planning and determination of educational objectives, which should be placed in terms of skills, competencies and attitudes. Further, one should select the content, organize them, systematize them and organizing them hierarchically and then choose strategies, linked to a didactic, noting that teaching is a pedagogical action. PBL is a method that should be done with proper planning Participant3SD4, (COBENGE2013).

4.2 Need to rethink the assessment of student performance in PBL and PjBL

Another point that came up in discussions on SD was on the evaluation of student performance. As mentioned by Participant4SD4 (COBENGE2013), "PBL develops the competence of leadership, communication, teamwork", this indicates the need for specific forms of assessment. Adds that some students spend long time in college, even if they express well, never had the opportunity and obligation to speak in public, sometimes lacked the courage, even if they are people who have a potential, and speak well. As highlighted Participant5SD4 (COBENGE2013) on valuation, also have to [change], we can no longer evaluate only part of the declarative knowledge but also procedural.

The question of evaluation becomes more delicate perceptions of students, since less objective aspects, such as participation in team, personal development, among others, may give the impression that there is no well-defined criterion teacher. These elements require subjective criteria that are discussed and constructed jointly with students. In speaking of this one in SD student:

Why the teacher is assessing us that way? Is giving the note of why people like the student that enjoyed some speech student, he participated for more? But sometimes, I'm really shy, just that I do not talk much, but sometimes a contribution is important. So besides the enduring knowledge, how the assessment is being made? Participant6SD4, (COBENGE2013)

4.3 Need for partnership with education professionals to implement and evaluate the implementation of PBL and PjBL

The application of learning experiences requires monitoring to verify their effectiveness and efficiency. The evaluation of the implementation of a strategy learning process is crucial for validation or rejection. This task could be performed by teachers themselves performing an implementation of a strategy in a particular learning environment. However, many teachers of higher education do not have the proximity to the practice of educational research, which complicates a more accurate monitoring of the results of an experiment. Even researchers in Engineering Education have often acute vision that allows them identification or diagnosis of a given phenomenon in the classroom, or even group of teachers.

In discussions held in SD from the lived experience and reported by participants was the need for explicit proximity of professional education in collaboration and evaluation of the implementation of learning experiences using strategies such as PBL and PjBL. The case of the University of Minho, where the approach of researchers in the field of Education strongly contributed to the advance in reflection and interpretation of results of learning experiences was cited. This integration is much weaker at this time, one of the reasons may be that self-efficacy is in charge of engineering professionals, who understand that they can make the management of the learning process as do other related to your area. However, knowledge about learning goes far beyond knowing how to conduct some experiments in the classroom. As mentioned by Participant7SD4 (COBENGE2013), "is not only an educator by reading Vygotsky, [is needed] a team discussing work " experiments conducted. Without that "effective participation of [professional] someone in the education area will be a failure, the attempt to implement active learning strategies." "The biggest problem in this methodology is the evaluation" and [is needed] to have anyone who has this specificity. The results "vary from year to year, the results are completely different and educational staff have this feeling and this expertise to help" in the implementation of these strategies.

4.4 The need for training teachers to work with PBL and PjBL

The training of teachers to work with PBL and PjBL was also considered in SD, mainly by the fact that usually the higher education teachers, and in the case of engineering education, are engineers with master's and doctoral title also in pure areas engineering. Thus, the teacher tends to repeat the form he had experienced in their education

Participant8SD4, (COBENGE2013), ie, if we lived a traditional school, it is very likely to go pursue their traditional way of teaching action. The condition that arises for the teacher researcher, who is valued for scientific production, does not motivate teachers to improve their skills in teaching process.

The question that arises is how to promote the training of teachers to work effectively and efficiently with the strategies of PBL and PjBL? It should be remembered that, in their great majority, are master's or doctoral degrees, which can be a deterrent to return to school as students to learn about education, and who are already teachers and are beyond apprentices. There is no interest in continuing education, because there is no incentive to be good teacher, only to be researcher.

The great problem of active learning methodologies, like PjBL, is to sell it to our colleagues, because we're here ... we like the subject, [and] are somehow we want to learn more about it and to understand a little ... [about] pedagogy, psychology. ... How many of us here, are engineers, 20 years of graduates, and learned a lot of hard engineering, but in no time we saw something of education? But I believe that if we are here until this time is because we like of Education and of challenges and are open to change. How to take this to our colleagues? Participant8SD4, (COBENGE2013).

Two proposals emerged from discussions in SD to ensure the education of teachers in the use of these strategies. The first was offering specialization courses in which are discussed topics of general education and training on specific topics on PBL and PjBL. The second was continuing education of teachers, with the assistance of teams of professional engineering and education, with experience in the use of these strategies. The second option has the advantage of objectivity in: indication of techniques to be used in conducting groups of students and teachers ; proposition fertile for use in working with students problems, identify the difficulties commonly encountered in working with students ; organizing the work schedules for projects . Anyway, all those elements that can be obstacles but for those who have experience in implementing these proposals, can be easily identified and overcome.

Few teachers accept the challenge to change teaching strategies. This isn't a specific problem of Brazil, other countries [were cited Portugal and Netherlands], and teachers resist change, as observed by Villas-Boas, et al (2012).

[Few] want monitor what is happening in today's world evolution, but don't have return. Or we change, or we will be swallowed, has no alternative. Lack humility to teachers who need to learn every day, ... the teacher must also improve their capacity. You can't implement these methodologies without you doing a training of teachers who will be involved, it is essential." Participant9-SD4, (COBENGE2013)

4.5 Some requirements for the teacher to work with and PBL and PjBL

When teaching strategy provides that the teacher presents students with or build an open problem whose solution there is the need for a plan with a wide range of possibilities, we are considering the non-teacher's knowledge about the results and the way forward followed. This can lead to uncertainty for this teacher and only with the clear option to learn along with the students, is that it will be comfortable to drive the work of learning.

For this teacher some requirements are needed to succeed in this journey. One is the humility to admit that either has no specific knowledge about the studied subject, as to admit that often is not aware about this new way of working with students. Admitting the need for training to perform the work in the classroom is essential to investigate and find ideas that will be fertile to make this work them Participant10SD4, (COBENGE2013).

Another necessary element is the teacher's curiosity. The teacher has to try to learn new experiences from the classroom. The theoretical references reported on SD are strong points of reference for the work of the teacher, who must, as well as learning new knowledge in engineering, research, read, try to reshape their perception of the world, expanding their understanding of these new themes. Without curiosity, the new knowledge is something "boring" as they say many of our students to not engage effectively with content that often present them.

The teacher must realize that the relationship of the classroom there are subjective aspects that determine learning and are present in the teacher-student. Emotions, as one of the participants of the SD, make the teacher feel the environment, what are the shortcomings; finally, there is the need to realize the student teacher. "I was made in a deterministic fashion and all things in life are all uncertain and probabilistic and now, today, many variables [at stake]."

Participant 11-SD4 (COBENGE2013), agreeing with speech Participant 10-SD4 (COBENGE2013), added that:

Using PBL we [the teacher] doesn't go to classroom, we go to emergency room, [because] you never know what will happen and what you will find, and sure enough [for] the issues raised, 100%, you don't know the answer. ... so it is important for the teacher to have the humility to recognize that he/she doesn't know, [but] they have to learn together. Just, it's possible an integration of the tutor, the teacher with the team, and gain respect from students Participant 9 - SD4 (COBENGE2013).

Operatively, teacher education must meet the changing referential work that the teacher must accomplish, namely, a job that does not have as a meeting point just classroom Participant 12-SD4, (COBENGE2013)). If you are looking for "developing autonomy in student if [what we want to accomplish] projects truth, [the teacher] has to let go of this model, ... Our flexible appointment times. This also requires teacher preparation for work outside the formal environment of the classroom.

Another element that emerged was the need to approach the industry Participant 12-SD4, (COBENGE2013), because there is that they are real projects that can motivate teachers and students in finding solutions that will be implemented effectively. Other types of problems created hypothetically are realistic and, more attractive they may seem, are not effectively applied and not have the appeal of the possibility of implementation.

5. Conclusion

All papers received and discussed at SD bring theoretical bases using classical educational authors: Ausubel, Brunner, Dewey, Kolb, Morin, Piaget, and Vygotsky. These authors are cited and underpin the work with a tenuous bond, for example, Dewey appears related to identifying real problems as elements of motivation to learning of students. Ausubel appears linked to meaningful learning that, in turn, is linked to real problems that promote the involvement of students in their solution.

Not is observed further discussion about elements of greater refinement of these theories aiming your understanding in the context of the implementation of PBL or PjBL, in order to confirming or contesting their elements. The little depth that this linking has presented, gives rise to the transition from one theory to another without a barrier of restriction, allowing interpretation and analysis of work in the classroom, in one or other theory. Make reference to Vygotsky or Piaget to justify the work done with PBL or PjBL not seem to make much difference in the discussion conducted on SD. It seems that the refinement in the use of these theories was not achieved and not yet part of the concern of researchers and at the interpretation of the results of their experiments.

More specifically, the PBL and PjBL's own references, appear quite restricted mode. Luiz Ribeiro and Penaforte that are the most cited authors in Brasil's cenários, didn't have their own ideas about the construction of knowledge from the use of these teaching strategies, but essentially are the great synthesizers of ideas of leading thinkers in education, and precursors who discussed these ideas about teaching and learning using this strategies. However, there is potential for the emergence of a deeper reflection on what do these teaching strategies and learning.

A strong element that can catalyze these results is to be closer to education area, and other specific areas such: Philosophy, Psychology (Psychoanalysis for more specific mode), Sociology, Anthropology, Neuroscience, which will bring elements to understanding the learner, including the teacher, beyond the student. Without this approximation, any strategy used in the mediation of knowledge construction is lame. The knowledge of Engineering, Physics, Chemistry or Mathematics are insufficient to advance the discussion and the interpretation of the results of learning experiences in engineering.

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An Inverted Math Course

Jens Bennedsen, Aage Birkkær Lauritsen

Aarhus University, School of Engineering, Aarhus, Denmark

Email: {jbb,abl}@iha.dk

Abstract

This article reviews the students view on an inverted discrete math course. The investigation is done by interviewing eight students who just have finished the course (out of 35 students). The students liked the course and almost all of them were very pleased with the new structure. The students prepared a lot more than what they do for a traditional course. The students appreciated the strict structure and the fact that they had to do mandatory reviews and in-class presentations.

Keywords: inverted classroom, video lectures, active workshops.

1 Introduction

In the ideal world, we (the teachers) would like to spend class time helping students to engage with the subject and material - not simply lecturing. This typically requires that the students know something about the topic on beforehand, so we assign readings to them. However Hobson (2004) refers to several studies that have shown that only 20 - 30% of the students read before class. The low number of prepared students then makes the teachers lecture and the prepared students to stop preparing; they become audience, so to say. So what to do instead of assigning reading to the students (that they do not read) and then (as a consequence) lecture all the time?

One answer is the “inverted classroom” (Lage, Platt, & Treglia, 2000a). The inverted classroom has its roots in the case study approach used by business and law schools, and in the humanities one can argue that they have used this method for many years when students are given reading assignments to complete outside of class to prepare for an in-class discussion. The term “inverted classroom” is also known as “flipped classroom”, “backwards classroom”, “reverse instruction” and “reverse teaching” (Wikipedia.org, 2013a). Many quote King (1993) as the origin for the idea of the inverted classroom. King had a very catchy title on his paper “From Sage on the Stage to Guide on the Side” - a term many have used afterwards to describe the role of a teacher in an inverted classroom course.

Lage, Platt and Treglia (2000a) describe the idea as follows: “*Inverting the classroom means that events that have traditionally taken place inside the classroom now take place outside the classroom and vice versa. The use of learning technologies, particularly multimedia, provide new opportunities for students to learn, opportunities that are not possible with other media. For example, the use of the World Wide Web and multimedia computers (and/or VCRs) enables students to view lectures either in computer labs or at home, whereas homework assignments can be done in class, in groups*” (p. 32). This was in 2000; now there is even more possibilities for multimedia and a lot of teaching material are available freely on the World Wide Web.

When designing such a new model for teaching, it is vitally important that there is consistency between the *learning objectives* provided for the course, the *teaching method(s)* used and the *evaluation* used. This is what Biggs (2003) refers to as *alignment*.

First of all we need to be very specific, when we define the learning objectives for the course. What competences do we want students to acquire in the course, described as what the students are able to do after the course has been completed. Next, we have to ensure that the students are going through activities in the course that enables them to meet the learning objectives. Finally, we need to choose an assessment form that shows whether students have achieved the stated learning objectives. The students must during the course have been exposed to activities that prepare them for the selected assessment form. This could be done, for example by working with activities, similar to what they are exposed to at the assessment. Whether these activities takes place in an examination at the end of the course or by assessment during the course.

In this article we describe work related to inverting the classroom. Following that we describe the context and the outcome of the research.

2 Related work

Many have reported on inverting the classroom, e.g. (Carlisle, 2010; Gannod, Burge, & Helmick, 2008; Strayer, 2012; Talbert, 2012; Toto & Nguyen, 2009) and all report on a positive effect of moving the lecturing (transmission) part outside the class and do more exercises, experiments and other active learning activities in class (assimilation). Almost all of the related work we found was using a quantitative research approach.

Carlisle (2010) describes how he have inverted an introductory Java programming class taken by 60 second or third year students majoring in computer science, computer engineering or information systems. For the course, they made 21 videos (18 on different Java topics and three describing the tool the students were to use). He report on findings from a survey answered by 57 students (no response rate is given). The course had three offerings taught by three professors and he report on their different styles. He found that the students liked the design; they preferred to have shorter lecturing time and more time in class to do actual programming assignments and they prepared more before class than normal.

Gannod, Burge and Helmick (2008) applied the inverted classroom idea to several courses in a software engineering curriculum at Miami University. They describe the redesign of several courses and give results from student surveys (a mid-term evaluation of the course) from a course in service-oriented architecture (the number of respondents varies from 16 to 22 - a low number). In that course, 65 podcasts were made available to the students (from very short (2-3 minutes) to long (50 minutes)). During the in class time, instructors answered questions from the students on the podcasts; after that the students worked on assignments. 100 % of the students found the podcast lectures helpful in reviewing material and concepts and allow class time for assignments, 86 % liked the inverted class structure, but 56 % agreed with the statement "use podcasts to supplement class lectures instead of replacing them". We think it is hard to conclude anything from their research.

Strayer (2012) reports on a comparative study on two introductory statistics classes; one taught in a traditional lecture-homework style and one taught in an inverted version using an intelligent tutoring system to replace lecturing. It was Strayer who taught both classes with approximately 27 students in each class. The inverted class met in a computer lab, the students engaged in activities tailored to strengthen their understanding of the more formal mathematical material presented in the tutoring system. Strayer found that students in the inverted classroom were less satisfied with how the structure of the classroom oriented them to the learning tasks, but they were more open towards cooperative learning and new teaching methods. Strayer's class is untypical in the materials it uses; normally videos are used.

Talbert (2012) describes how an introductory course in MATLAB for a diverse group of students (Engineering, Mathematics, Mathematics Education and Elementary Education) was designed. They were only allowed to meet 75 minutes pr. week. The course used videos from Mathworks in the first offering, but in the second the instructor created 41 different videos (screencasts), each on a single topic lasting 6 - 8 minutes. Right after the weekly meeting a post of the tasks the students had to do before next class (i.e. what to do in the six days outside class). The post contained an overview of the upcoming class, a list of videos, a list of competences the student should master before class and mandatory assignments to do (simple, mimicking the examples on the screencasts). He concludes that the inverted class was a success where the students accepted the form in the end.

Toto and Nguyen (2009) reports on the use of video materials in order to invert an Introduction to Work Design course. They made two interventions in the course, and for each intervention collected data on the students' attitude towards the flip. 89 students participated in the course, 32 of those answered three surveys. The students found the topics chosen for the inversion was well suited for the format. The students preferred to attend face-to-face lectures over videotaped lectures but they also preferred to use class time for problem solving and hands-on activities rather than attending a lecture. In general students enjoyed the format but they noted practical problems like the time it took the instructor to get around in class to help was sometimes long.

3 Context

The research is an intervention study, in a discrete math course, where the pedagogical design is changed. The course (ITDMAT) is a 5 ECTS point (60 ECTS = one year of fulltime study) elective course offered to students in their final year of their professional bachelor study in information technology (ICT) or electronics (E) at Aarhus University School of Engineering. Before this course, students have had two years of mandatory courses and half a year of internship (and some of the students half a year of elective courses). The elective courses are taught in a quarter structure (a quarter = 7 weeks of teaching and 3 weeks of exam). This class had 35 students; the course language is English and had two teachers.

Prior to the course, the following was mailed to the students to ensure that they “knew the rules of the game”:

ITDMAT is a 5 ECTS course. 60 ECTS is one year of full time studies => 5 is one month of full time studies. This means that we expect you to work in total 150 hours for this course or 18 hours pr. week for the 7 weeks (in total 126 hours) plus 24 hours for exam preparation (much of which you will have already done during the course). On average we expect that you use your 18 hours per week as follows:

- *Reading books, watching videos, answering MCQs: 6 hours*
- *Class hours (including some time to do hand-ins): 8 hours*
- *Hand-ins, review of hand-ins: 4 hours*

So — it is intense and you need to work continuously during the quarter!

3.1 Schedule

The course was scheduled two times a week Tuesday afternoon and Friday morning. Both Tuesday and Friday is four teaching hours (a teaching hour is 45 minutes teaching and 15 minutes break).

Prior to the class on Tuesday, the students were expected to have watched the videos assigned to the weeks topic and tested their knowledge on a quiz.

Tuesday started with general comments on the students mandatory hand-in (see section 3.4), typically 30 minutes. It was mostly done using examples from the students' hand-ins to illustrate the typical problems. The purpose was to give some general feedback. Then an overview lecture for this week's topics where the students can ask questions about the material (typical 45 minutes). Following that, the students did two workshops. A workshop is a problem that students solve in small groups for 15 min and then 7 minutes of presentation of the work by a selected group. The problem resembles a problem that could be in the mandatory assignment. The last hour was used on this week's mandatory hand-in, with the teacher as a supervisor, to get the students started and help them with initial problems.

Friday started with three workshops followed by an hour where the students worked with the hand-in in order to help students who had problems with the hand-in. The students in groups of two or three prepared an exam question (for details on the examination (see section 3.4). There was almost a one-to-one correspondence between a given weeks topic and an exam question. The idea of the preparation of the exam questions was two folded: Firstly to have the students reflect on the topic and create their own overview of the topic. Secondly to have them prepare for the next activity, a trial exam. The trial exam should give help the students in speaking about math and train the in the new examination format.

3.2 Learning outcome

The learning outcome of the course was the following:

When the course is completed, the student is expected to be able to:

- define and analyze the fundamental concepts of propositional logic and predicate logic,
- explain and apply modeling using discrete mathematics such as sets, lists, functions, relations and graphs,
- describe the principles of various proof techniques such as induction, contradiction.

3.3 Learning materials

In an inverted class, the students' should be able to acquire the knowledge they typically get from the lectures before the class takes place. Typically this is done by some sort of video mediated material. In this course we have chosen prefabricated videos from different sources and in different forms:

1. 20-30 minute power point cast on a given (larger) topic from project polymath (see e.g. <http://www.youtube.com/watch?v=x65OJU8Uq4>).
2. Videos of teachers describing a precise topic on a board; typically 10 minutes long (see e.g. <http://www.youtube.com/watch?v=x65OJU8Uq4>)
3. Short screen cast; typically 10 minutes long from Grand Valley State University, department of mathematics (see e.g. <http://youtu.be/6qTzP03waOA>)

4. Long, recorded lectures (1 - 1½ hour) (see e.g. <http://ocw.mit.edu/courses/electrical-engineering-and-computer-science/6-042j-mathematics-for-computer-science-fall-2010/video-lectures/lecture-3-strong-induction/>)

All of the videos are all freely available on YouTube. None of the videos are produced exclusively for this course but chosen by the teachers. Discrete Math is a young topic so the notation is not standardized (e.g. some use \Rightarrow for implies while others use \rightarrow), so some confusion on notation was existing. To help the students we inform them on the differences on beforehand.

Apart from the videos there was a textbook assigned. To help the students assess their own understanding a quiz for each topic was created.

3.4 Assessment

The assessment of the course has been done as follows (three elements):

- **Mandatory hand-ins.** Every week the students had to hand-in an assignment. There are two parts on each hand-in. Firstly the hand-in in itself (deadline Friday before midnight). Secondly the students had to review three fellow students' hand-ins. The reviews had to be handed in before Sunday at midnight. In the review they had to evaluate if the hand-in is acceptable and make comments. If the hand-in was not accepted the student were not allowed to participate in the examination; that decision was taken by the teachers.
- **Presentations in class.** All students had to do presentations in class at least one time during the course. This was required to be allowed to participate in the examination.
- **Examination.** The examination at the end of the course was oral, structured differently from traditional exams. It consisted of two elements:
 - o An oral presentation on a given topic, the student draws a question.
 - o Review of two fellow students' presentations.

Part one counted for 75% of the grade, part two for 25%.

The examination was trained during the course (see section 3.1). The students worked with preparation of the examination questions in class.

4 Research design

The argument for flipping a classroom is the basic belief that learning is done in a constructivist way (Lage, Platt, & Treglia, 2000b). The Danish professor in pedagogy, Steen Larsen (1998) have described constructivist learning in the following way:

You will learn something if – and only if - you

1. create¹ something in a process
2. that you are emotional involved in and
3. that requires skills that you almost meet.

The answer does in fact include two messages: the first one is the “if” part. We are convinced that it is true in every case – and in Larsen (1998) both strong arguments and experiments justify the “if” part. The “only if” part is in some sense stronger: it expresses that there is no other way to learn: every process of learning have to contain actually working with something you are emotional involved in and the task you are working on have to be on the border of your current skills (zone of proximal development). The “only if” part is not true in all cases: there exist some people that may learn something - in the above sense – by just reading or hearing about it. But there are very few of them – and we should not practice our teaching for this small group of well-equipped people.

The research question in focus here is “How do students experience a flipped discrete math course and do they feel that the design supports their preferred way of learning?”

The constructivist knowledge claim holds the position that meanings are constructed by humans engaging with the world. It arises from works such as Berger and Luckmann (1969) plus Lincoln and Guba (1985). The generation of meaning is always done in a social context. The researchers acknowledge that their own personal, cultural and

¹ The word create is used in broad sense including abstractions, reflections, constructions, ...

historical background influences the interpretations, and they position themselves within the research field. Consequently, we need to make a research design that focuses on the students understanding of the usefulness of the actual course design. We have therefore chosen the following research design:

In order to evaluate the effect of the new design of the course, we decided to interview 10 students about their view on the design. The researcher (second author) was not involved in teaching this course or other courses that students have had or will participate in. The students participating in the interviews were chosen by random (out of a total population of 35 students for the course). They were not given any credit for participating in the interview.

4.1 Interview method

It is our opinion that we, by using qualitative interviews, can get more useful empirical data. The qualitative interview is suitable for uncovering complex information structures. In contrast to the survey interviews, qualitative interview studies are open and not standardized. The qualitative interviews has an interactive nature that makes it ideal for getting the informants' individual view of reality ahead. Although the interviews were planned in advance with an interview guide, this interview method allows for development along the way so the relevant issues that arise can be followed. The interviews fall under the category Steinar Kvale (2005) calls semi-structured interview: *"It has a number of themes to be covered, as well as suggestions for questions. But at the same time, there is openness to changes of the order of questions and form so that you can follow the answers interviewees give, and the stories they tell"* (Kvale, 2005 p 129).

4.2 Execution of interviews

Prior to the interviews we prepared an interview guide as a framework for the interviews. Our interview guide consists of keywords, which are prepared in preparation for the interview. The guide worked well, and the order was almost followed.

We began the interview with a brief introduction to the purpose of the interview. As a reference for the questions, we first asked the students of their experience of what a traditional course means and after that we got into the different questions about the new design:

- The new course design, what was new
- Course materials
- In class experiences
- Outside class experiences
- Exam
- General comments

The interviews were recorded on audio files.

4.3 Participants

All of the students in the course were male; consequently all the interviewed students were male. Eight students were interviewed. Most of the interviews were done right after the examination; two was done two days after. Initially 10 students were asked if they would participate, one could not find the time and one did not like to be interviewed shortly after the exam.

Table 1: Data about the participants

Reference (name)	Age	Study programme	Semester	# of courses at the same time
SO	25	ICT	6	2
LP	24	ICT	7	0
FT	26	ICT	7	0
JI	26	ICT	7	1
JK	24	E	6	1

KN	26	ICT	6	0
RJ	23	E	6	2
TH	23	ICT	6	1

4.4 Analysis of the data

As mentioned previously, the interviews were done by the second author who is not involved in the course (he does not teach on either of the two involved study programmes). All of the interviews were analysed by both of the authors. The authors listened to the interviews and noted relevant views on the general topics.

There has been no transcription of the interviews in their entirety, but condensed view of relevance to our perspective in the study. By selecting this method we are aware of some errors that may affect the conclusions. First of all because we do not get the precise readings and secondly when we translate to English some meaning might get lost. This we considered acceptable as what we want to retrieve from the interviews are trends in the development and status more than it is facts.

The analysis has been inspired by Kvale's question: *"How can the interviews help me to expand my knowledge of the phenomena I examine?" ... "How do I analyze what my interviewees told me so that I can enrich and deepen the significance of what they have said?"* (Kvale, 2005 p. 181 - 182).

Specifically, we use keywords from the interview guide to first organize and then condense the eight interviews.

5 Findings

This paragraph describes the findings from the eight interviews. It is focusing on the students view of a traditional course, the new course design, the used learning materials and the work outside the classroom.

5.1 A "traditional" course

Talbert (2012) describes how university teaching has been for hundreds of years:

1. *Students come to a class meeting during which a lecture is given. Students take notes and occasionally ask questions.* (what learning theorists call transmission)
2. *Following the lecture, learners are assigned work to be completed outside of class. This usually takes the form of homework, test preparation, or writing papers.* (what learning theorists call assimilation)
3. *The outside-of-class work is submitted or assessed in class. The cycle then repeats.* (p. 1)

Before interviewing students about the inverted course, we asked them to describe a traditional course - did they agree with the description from Talbert? Not quite but all of them had the same understanding of a traditional course - the first approximately 50% of the allocated time in a given week was traditional lectures; the rest was exercises where the teacher was walking around. As one of the students put it:

"It is normally split 50-50 in lecturing and exercises ... lecturing is where the teacher stands in front of the board and talks ... exercises are when we are in the class working with exercises and the teacher walks around" [LP]

Most of the students had the understanding that teachers found the lecturing part to be the most important:

Almost all of the time there is a very long lecture and exercises that is ... if we have time [SB]

So the "normal" teaching in these two study programs is most of the time is spend on transmission but also some assimilation is taking place.

5.2 The new design

This section describes the students view on what was the most different elements in the new course design.

5.2.1 Feedback

In general the students were satisfied with the feedback they got. The teachers did not spend much time giving feedback; most of the feedback came from the fellow students; some of the students wanted a little more feedback from the teachers

It would have been nice to have some feedback from the teachers ... one could have a little more critical review of it .. it is ok that one's classmates have a view but in the end it is the view of the teachers that decides what is right or wrong [FT]

Many of the students found it difficult to give feedback in the beginning, but they all found it to be much easier in the end

It took some time to figure out what good feedback is. There were a little "Law of Jante" [(Wikipedia.org, 2013b)], you would not point on others errors if it was wrong what you thought then you look like a fool. That way of thinking one need to get rid of [RJ]

5.2.2 Structure

The course had a tight schedule, something not happening in many courses at the school of engineering. All of the interviewed students found the structure to be beneficial to them. They were all talking about the tight schedule and the required work they had to do in order to be allowed to participate in the exam; all of them said that the structure kept them on their toes and helped them with managing their time. As some students said:

It was structures and it was .. well it was good. I liked the way it was done .. it gave a bigger incitement for starting every time since you had that mandatory assignment you had to understand what it was about [JI]

It was cool that there were this clear division ... we will be doing this in this hour and that in that hour, so we know what to do ... in other courses it have been like he [the teacher] talk until he have finished and then you can do exercises for the last part [JK]

The structure have forced me to work through it ... it have been going quickly but I have never felt like I was behind due to the hand-ins. [LJ]

5.2.3 Talking about mathematics

One of the goals of this course is that students shall be able to communicate about mathematics. To get alignment with this goal, there were a lot of presentations during the course; after a workshop a student should present and at the trial exam one student should present and two students should review. In the beginning it was difficult for the students to do the oral reviews; they found it difficult to figure out what they should focus upon. But in the end of the course - and in the exam - the students had gotten used to it and found it easier to do.

I did the third trial exam [was a reviewer] and I found it difficult to see that you should not comment on the presentation but on the content ... I did not give much feedback [there] because I found it hard ... it was easier at the exam because I have learnt it [JI]

Some of the students found it a little challenging to review their fellow students. They are classmates and it was difficult for them to critique their classmates. Especially in the beginning, when it was not clear that the critique was not blaming the reviewed student but the focus was on the reviewer - was he actually able to give constructive critique?

The students had one hour prior to the trial exam to prepare. They typically did that in groups of two or three. The purpose of the activity was to have the students' reflect on this week's topics. In general it worked that way.

We made an agenda ... it was normally not finished but it was a good start [for the real exam] [LP]

Apart from the trial exams, each week had five workshops. The students found the workshops to be of a good learning value to them. Most of the stressed the fact that the mandatory presentation was important (and the cold-call procedure for selecting who to present)

I found it [the workshops] to be working very well, you were forced to do the stuff so you did it and the fact that you have to present it makes you think even harder about it ... you want to be sure when you can be selected to present it [JK]

5.2.4 Hand-ins

In the interviews we asked the students about what was special and new in the new course design. All the interviewed answered, that they did not earlier get that amount of mandatory hand-ins. Also the fact, that there was put so much emphasis on hand-ins where new to the interviewed. As one student expressed it:

"We have one hand-in every week ... after that [in class] we get an short lecture and exercises, but the balance is very different compared to earlier courses, ... the lecture is much shorter and we have a lot more time to work on exercises" [JI]

Another thing that was new to all the interviewed was the review part. No one had earlier tried to make review on hand-ins from fellow students (see section 5.4.1).

5.3 Learning materials

In the course we have used several different learning materials: videos, quizzes and a book. In general the students were very positive in their view on the learning materials.

5.3.1 Videos

As mentioned in section 3.3, several types of videos were used. All of the videos were produced by others than the teachers. This is different from what e.g. Overmyer (2013) describes as used in a flipped classroom: “*What used to be classwork (the “lecture”) is done at home via teacher-created videos*”. None of the students found it to be of lesser value that the videos were created by others. One student even found it to be positive:

I think the most different is The most different is that the lectures are done on videos. I think that is very smart. It is something that I have had in mind and think is a very good since you are sure that the lectures are well prepared and worked through. It is not a teacher that stands there and on the spot invents explanations ... it is better with something that is planned and polished. Then you can ask the teacher afterwards about the things you do not understand.[FT]

This was the first course where the students were exposed to such a heavy use of video-based teaching. In general the students found it to be very useful.

We have had videos used in teaching in prior courses but that have been related to exercises or labs, here it was the actual teaching ... here it is video teaching and not just tutorials. [RJ]

The students had a preference for the short and medium length videos. They preferred that they were to the point and it was easy afterwards to consult the video if they were in doubt about something related to the topic. Several of the students did not watch the long videos. Their explanation was lack of time, since the viewings of the videos were to take place during the weekend or Monday.

Some of the videos had a form where the students were expected to stop the watching at a certain point and reflect on the theory or answer question (like the style that has become popular in many MOOCs now). Many of the students liked that format and said that they actually paused the video and thought about the question.

In some of the videos he asked a question and you should stop the video ... it worked actually quite well [KN]

When asked if the students could do with just the videos (i.e. no reading material) almost all of them found it of good value to them to be able to watch the videos, read the material and have the short overview lecture. Different students used different strategies when learning. Some of the students watched the videos, took notes and read the book to check their understanding. Others started on the hand-in and then consulted the book when needed. A third group started with the book and used the videos for recapturing the book.

I would not like to live without it [the book] [LP]

5.3.2 Quizzes

To help the students check if they had understood this week’s topic the teachers created quizzes for the students. They were voluntary. In the beginning a few students used them but after a couple of weeks they were not used at all. The students found that they got enough of feedback via all the other feedback giving activities.

I used them some in the beginning but then it [the other activities] started to take more time ... so I deselected them ... they worked well but they took too much time [KN]

5.4 Work outside the classroom

In this section we will describe the students’ view of the work outside the classroom.

5.4.1 Reviews

One of the mandatory things the students should do every week was to review the hand-in from three other students. Some of the students found the reviews they received beneficial, but there was a general consensus on a big difference in the quality of the reviews. Some students just said ok, other gave more in depth reviews.

Reviewing other was generally seen more beneficial. The students found it in general a good learning experience. The students were not to give grades but to inform the teachers if they found the hand-in to be acceptable or not.

I did not learn a lot from it [reading others’ reviews] ... I think I learned more from doing the reviews [JI]

I liked to review the others in order to see how they have solved the exercise [JK]

5.4.2 Workload

In 2011 Aarhus University did a survey regarding the students' wellbeing (Jensen, 2011). Among other things they students were to self-report on their workload. In average, a student at the university worked a little less than 30 hours/week, a low number compared to the expected 50 hours/week.

Prior to the course, the teachers send out an email describing their expectations (see section 3). One of the expectations was that the students studied 18 hours (for this course) a week - 8 hours in class, 6 hours working with the hand-in outside class and four hours preparing (watching videos etc.). The students in general said that they had been working 15-20 hours a week on this course

The teacher send us an email where he wrote in much detail that you are expected to work six hours on this and four hours on that ... just when I got the mail I thought, "Wow, this is going to be a hardcore course" but it is actually quite nice to have some kind of indications and to know that when you have worked approximately six hours on the hand-in then you have used the correct amount of time on that. [KN]

Some of the students worked even more than the expected 18 hours

I used more hours than I was told to use [KN]

6 Conclusion

In this article we have analysed interviews with eight students who have participated in an inverted math class. All of the interviewed students found the flipped format of the class to be very beneficial in their learning. As Becker and Watts (1995) write. *"Great orators should lecture. The rest of us should consider using a variety of teaching methods to actively engage our students and reduce the amount of time we spend lecturing to audiences that are often captive in the short run, but all too willing and able to vote with their feet in the long run"* (p. 699). However, from the interviews it is clear that it is not the inverted nature of the teaching in isolation that was the dominant feature the students mentioned when asked about the most important feature of the design, it was the very precise structure and the mandatory elements like hand-ins and reviews. As one student note:

I definitely feel like I have learned more here than in other courses using the same amount of time ... the way where you every week need to concentrate on the course. I have been missing this in other courses at the university.[SO]

When it comes to alignment in the course, all students interviewed answered that the course design had a very good cohesion, there was a good alignment. As one of the students said:

There is a very good cohesion between the teaching and the way the exam was planned. ..The way they have connected exam to the teaching, does that... [FT]

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Using Active Learning to prevent evasion of Engineering

How to deal with institutional nightmares assessing first year courses in Engineering

*Miguel Romá**

* Signals, Systems and Telecommunication, Department of Physics, Systems Engineering and Signal Theory, University of Alicante, Alicante, Spain

Email: miguel.roma@ua.es

Abstract

The development of the new degrees, motivated by the European Higher Education Area (EHEA), at the Valencia territory (Spain), implies the evaluation of each degree by an official accreditation agency. This accreditation process is crucial to determine which degrees will continue and which of them will not. This fact is, obviously, a key factor for University managers all across the affected geographical area. Even though searching for quality can be an interesting goal, whenever the indicators chosen to quantify the quality of the degrees are not the correct ones, this can lead to undesirable consequences, in the same way how we assess students will determine their behaviour.

Keywords: evaluating active learning, quality in University degrees.

1 Introduction

It is quite common to see how learning institutions, especially Universities all around the world, are presenting themselves as units with high levels of accredited quality or even excellence. These quality tags seem to be something positive at the very first impression. Notwithstanding, if we think in quality control as an assessment of the institution, it is clear that the indicators used to analyze the quality will have a direct impact in universities directives, leading the internal organization of the institution towards complying with the designated quality parameters. The main goal of this work is to promote a reflection about the convenience of the implementation of Quality Control Strategies at University level. Moreover, the impact that this kind of quality control can have at teaching and learning levels will also be discussed specially focused on first year courses, with higher number of students that usually present lower maturity levels. The aim of the paper is not to answer the question of how to deal with this situation, but to reflect about the roots of the problem and its derivations.

1.1 Motivation

The development of the new degrees, motivated by the European Higher Education Area (EHEA), has had a profound impact of the university scenario in Spain. The new learning schemes that theoretically will compulsory be used, with the inclusion of new quality control strategies, appear to be a promising idea. On the other side, having to migrate to the new university model at zero cost has been, clearly, an impassable obstacle to really implement the proposed model. However, while almost every one at universities knew that the real implementation the EHEA model were reduced to a pipe dream, the quality control was maintained. At the Valencia area (Spain), a part of the quality control implies the evaluation of each degree by an official accreditation agency. This accreditation process is crucial to determine which degrees will continue and which of them will not. This fact is, obviously, a key factor for University managers all across the affected geographical area. Even though searching for quality can be an interesting goal, if the indicators chosen to quantify the quality of the degrees are not the correct ones, this can lead to undesirable consequences, in the same way how we assess students will determine their behavior.

These problems, along with most others, are inspiringly covered in a highly recommendable essay, written in Spanish, entitled “la Universidad comprometida”, that can be translated as “the committed University” (Manzano-Arrondo, 2012). This text widely covers how different environmental constrictions have led to the actual University model.

The paper is organized as follows. Chapter 2 covers the concept of quality, and how it is developed at business and university levels. The particular implementation of quality control at the Valencia area and the University of Alicante are presented in chapter 3. Chapter 4 is focused on the learning implication of the application of the quality control scheme, ending with the conclusion. Most of figures included in the paper are parts of institutional documents about quality control models, and I have decided to show them in their original appearance in Spanish. However all the relevant information is translated in the text.

2 The goal of Quality

The reading of the work mentioned above (Manzano-Arrondo 2012), has proved me with most of the ideas covered in this chapter. In this chapter, a quick view of the origins of quality control systems will be presented, together with its implications of the adoption of this model at teaching institutions, with a close vision of the quality program at the University of Alicante.

2.1 Origins of quality control

Quality is a good sounding word that evokes positive feelings. Anything with objectively measured quality should produce good results. Notwithstanding, there has been a commercial tendency to associate quality to less tangible concepts, for instance, the association between quality and price. It is not difficult to find people assuming that something with higher price should be something with higher quality. As good as quality refers to subjective attributes, every product can boast of having quality. Enterprise effort is addressed directly to strengthen product image and its relationship with quality. As quality is affordable to any company, in 1985 appeared the term Total Quality Management (TQM) as a way to designate that total quality can only be acquired if the company is being managed in a proper way. As a result of these approaches, two key elements were defined, client/consumer satisfaction and company management. The last step, trying to go further, is collected under the term excellence, with its main focus in client satisfaction.

2.2 Quality control at University level

As the Quality concepts has being widely use in the last years, specially at commercial levels, universities are making a great effort and investing personal and material resources to increase quality levels. To illustrate this fact, Figure 1 shows a special report about quality edited by a local newspaper, commemorating the Quality World Day, published on December 14 2013. The main headline is "Quality: key concept". It is noticeable that two out of eight pages were about the two universities of Alicante area (UA, University of Alicante and UMH, Miguel Hernández University). The headlines leading these articles can be translated as "UA committed with continuous improvement" and "UMH stimulates teaching talent". The headlines of the UA article is follow by the sentence: "with the introduction of new degrees in 2010, the University of Alicante established a quality control system that allows them to demonstrate and verify these degrees and to track their performance". It is important to realize that half of the space, regarding both institutions, is commercial, so the universities have invested resources in image promotion. It is clear the intention of university governors to provoke the relationship between the concepts of university and quality.



Figure 1: Special report about Quality including University information.

But, in the same way that professors have the ability of define the way in which our students will work by setting the assessment methods, the selection of the quality indicators used to measure and quantify the quality will have a similar effect on University leaders. Many objective and easily measurable indicators have been selected, but are they measuring what we want or what we can? Do we have a clear and accepted idea of what quality means? Does it make sense to apply quality models created by enterprises for commercial proposes? Using a commercial-based quality model implies the translation of terms used at enterprise models to the learning environment. In this sense, University occupy the role of Enterprise, Education can be seen as Investment, Student as Client or Consumer and the Academic Vision as Client Satisfaction. These assumptions can lead to assume that, as the well-known commercial principle that states that client will always have the reason, the relationship between University and students, can be understood as the relationship between enterprise and consumer. In this way, one of main Institutional concerns will be students' satisfaction (Temple 2005). Even though looking for students' satisfaction is not a bad purpose by itself, if it is assumed as one of the main goals of our universities its effect can be undesirable. If students' opinion is used as one of main tools to "measure" the quality of the teaching work of teaching staff, as it happens in my area, the goal of professors can dangerously turn from trying to provoke profound learning to ensure students satisfaction.

There is another significant aspect pushing strongly in the same direction. One of the main indicators used to measure the quality of an institution and to determine its position in a ranking is its research productivity, measured mainly by the number of papers published in highly scored journals. As a result of this fact, universities encourage their teaching/researching staff to get as much papers as possible by considering this index as one of the main indicators while assessing promotion values, and computing it with a higher weight than teaching merits. As a natural consequence, teachers will find very much productive to focus their effort in research (to be more precisely, in publish papers) than to develop a coherent and committed teaching work.

The final day by day situation means that people working at the institution (not including the governors or managers) are the final agents that have the responsibility to ensure the achievement of quality goals. So, wanted or not, we, as professor, are assuming an active roll in the good or bad consequences that the implementation of these quality control schemes may have on the actual university situation. In this sense a bipolarized scenario has been created affecting the research and teaching staff: the first group comprised of those becoming a piece of the system without asking themselves if this is correct or not, and the second one including those of them trying to work in accordance to their coherence sense, that can agree or not with the institution goals. In my opinion, the majority of professors feel more comfortable positioning themselves in the first group.

3 Quality control at University of Alicante

In this chapter, the main quality indicators used in the assessment of degrees at the University of Alicante will be presented, with details concerning the Sound and Image in Telecommunication Engineering (SITE) degree.

One of the steps being compulsory for a University to get authorization to offer a degree is to present a memory including a complete description of the syllabus, the social and economical environment related to the degree subject, the resources available and so on. The first page of the memory concerning the SITE degree can be seen in Figure 2. In the transition of the old degree structure to the new one, according the EHEA, every new degree evolving from an older one, must include in its memory some data concerning how it is going to be adapted to the new scenario. As a part of this document (Universidad de Alicante, 2010), there must be a chapter entitled "Expected results". In the case of reformulation of existing degrees, the expected results have to be based upon the evolution of the selected indicators in the last years. With respect of the SITE degree, the indicators included in the memory are called efficiency rate (ER), gradation rate (GR) and dropout rate (DR). These indicators are obtained considering a particular number of years, as stated in the memory. Their respective meaning is:

$$ER = \text{total \# degree credits} / \text{total \# registered credits (\%)}$$

$$GR = \text{\# graduated students (in } d \text{ or } d+1) / \text{\# entering students (\%)},$$

where d is the duration (number of years) of the degree

$$DR = \text{\# incomings} / \text{\# dropouts (\%)}.$$

The memory states (translated from Spanish) "the proposed rates for the selected indicators are going to have into account possible improvements in the expected results as a consequence of advances affecting information processes, orientation and coordination, learning innovation and the use of learning-oriented methodologies, and an appropriate workload".

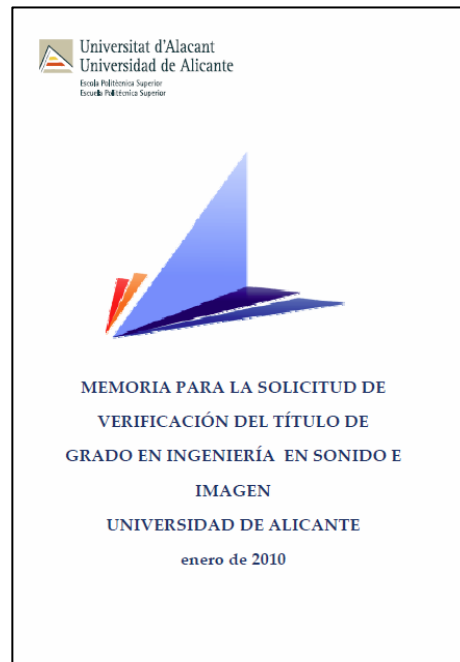


Figure 2: Cover of the memory (in Spanish) for the request of verifying SITE degree.

The evolution of the indicators, as collected at the degree memory, between 2005 and 2007, as well as their respective expected values in the proposed degree, is summarized in table I.

Table 1: Evolution of academic results and proposed values for SITE degree

Year	ER (%)	GR (%)	DR (%)
2005	68	7	24
2006	67	12	40
2007	71	7	42
Average	65	9	34
Proposed	>65	>25	>20

It is noticeable the big difference found between average and proposed values concerning the gradation rate and the dropout rate.

Obviously, degree contents are also taken into account as a part of the assessment of every memory.


Periodically, every degree passes through an accreditation process with the theoretical goal to ensure a high quality level of the higher education system. In the Valencia area actual accreditation of degrees quality is based, mainly, in the comparison of the rates presented in the memory with those obtained at the evaluation moment.

Moreover, University of Alicante has defined its own quality program, developed and detailed in several documents. One of the documents with a greater real impact in degrees assessment is called *PC12 Academic results analysis* (Universidad de Alicante, 2008). This document (cover shown in Figure 3) explains the procedures established to perform the quality control, the data to be collected in the assessment process of any degree and the way to present the results as well, defines who will analyse the data and who will take decisions after the analysis. The flowchart of the application of this procedure is presented in figure 4. The document includes the indicators listed in Table I complemented with some others including effectiveness rate (EfR), success rate (SR). To obtain these rates, the procedure is:

$$\text{EfR} = \# \text{ passed credits} / \# \text{ registered credits (\%)}$$

$$\text{SR} = \# \text{ passed credits} / \# \text{ presented credits (\%)}$$

where the main difference between the two, is that the first one is related considering the number of registered students, while the second one takes into account the number of students that have passed through the evaluation process.

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RESUMEN DE REVISIONES		
Número	Fecha	Modificaciones
00	30/04/08	Edición inicial

Elaborado/ Revisado por:	Aprobado por:
Fdo. Viceministra de Planificación Estratégica y Calidad Fecha: 05/09/2008	Fdo. Rector Fecha: 05/09/2008

Figure 3: Cover of the document (in Spanish)) describing the academic results analysis.

These two indicators are specially used because they are obtained considering just the results of one particular year, so they are used as the basis of the year by year study of the evolution of degrees.

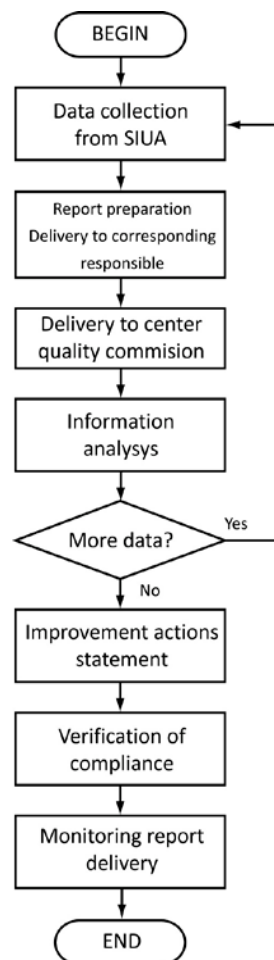


Figure 4: Flowchart of the Academic results analysis procedure used at the University of Alicante.

The internal quality control system is recognised by a national accreditation agency (ANECA, national agency for quality assessment and accreditation) as being following the criteria stated at the “systems design and development of internal quality management of higher education”, by means of a programme named AUDIT. Moreover, ANECA agency is member of the European Quality Assurance Register for Higher Education. Figure 5 presents the certification emitted by ANECA to the Polytechnic University College (EPS).



Figure 5: Certification (in Spanish) of the quality control system of the EPS under the ANECA standards.

Analysing the information provided in this chapter, together with more documents available on line at the university and regional and national government web sites, it can be concluded that there exists a clear, transparent, standardized and well documented quality control system.

4 Learning implications of Quality control scheme

The adoption of the EHEA scenario in Spain has had two major implications. On the one hand, methodological changes have been compulsory, without taking into account if there were or not resources enough to carry out the new proposed methods. On the second hand, the adoption of new quality standards and accreditation procedures suppose a great pressure to university communities, as they were exposed to close those degrees not passing the quality controls. The first factor causes pressure at the teaching levels, as professors are the layer who has to deal with methodologies in conditions very far from ideal. The second factor affects primarily to institution governors, who move the pressure, again, to the teaching layer, as the majority of indicators are based directly on professors' work. This last source of pressure is of particular concern as there has been a process that could be called "*university bubble*". For the last years, the number of universities, both public and private, has increased without a clear control. In Alicante area, with about 2.000.000 inhabitants, we can find three public universities, one private and two more private ones that will start operating the next year. Two of them have several campuses around the geographical area of Alicante. This situation can be extrapolated to the rest of the country. The uncontrolled increase of the number of nearby institutions has led to the offer of the same or very similar degrees in centres few tens of kilometres apart. The threat of closure of degrees depends not only of their quality parameters but also of its particular situation, including political reasons, compared with the close similar offer.

The inclusion of quality control programs is not a bad decision by itself. Even more, assessment of quality will, for sure, provoke improvements in several areas affecting institutions being controlled. The question is how the quality is evaluated, the consequences of not passing quality standards and the measures taken to ensure compliance with quality programs. The next paragraphs will emphasize only on the "dark side" of this environment. The analysis will be focussed on first year courses as they present the worst conditions: higher number of students per group, lower maturity level of students, less experience concerning higher education, high percentage of compulsory subjects... So,

first year courses are more susceptible of getting lower quality rates, and, consequently, first year courses professors will suffer more pressure.

Our experience about the quality control procedures is that the main indicator is based upon the rates defined in chapter three. In fact, the procedure explained in document *PC12 Academic results analysis*, in the section defining how to report the results of data collecting, states that those courses not getting particular minimum rates must be highlighted in red colour. In fact, there is no other item having to be red coloured. Figure 6 illustrates this section of the document.

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II. DATOS GENERALES DESAGREGADOS A NIVEL DE ASIGNATURA

- II.1 Tasas de No Presentado/ Éxito/ Eficacia, desagregadas por asignatura**
 Aparecerán resaltadas en rojo aquellas asignaturas que para el curso de referencia, "X", obtengan:
- Tasa de NP $\geq 50\%$;
 - Tasa de Éxito $\leq 30\%$;
 - Tasa de Eficacia $\leq 20\%$

Figure 6: Fragment of the indication (in Spanish) to red mark the courses not getting minimum quality rates.

Besides, after each semester an internal report is sent to the corresponding professors including the results of indicators EfR and SR for all the courses. In this report, the courses with the lowest values are also red marked. Figure 7 is a fragment of the document corresponding to the rates of first year courses. The information included in each column corresponds with course, number of registered students (*Matriculados*), number of passing students (*Aprobados*), number of students that made the exam (*Presentados*), and effectiveness and success rates. The two columns of the right side present the maximum, minimum and average values for the EfR and SR for first and second semester courses.

	Matriculados	Aprobados	Presentados	eficacia	Tasa de éxito	EFICACIA		ÉXITO	
	2.012	2.012	2.012	2.012	2.012				
ELECTRÓNICA BÁSICA	104	44	92	42,31%	47,83%	máximo	56%	máximo	68%
ANÁLISIS DE CIRCUITOS	111	50	101	45,05%	49,50%	mínimo	28%	mínimo	36%
FUNDAMENTOS DE PROGRAMACIÓN I	104	29	80	27,88%	36,25%	MEDIA	43%	MEDIA	53%
FUNDAMENTOS FÍSICOS DE LA INGENIERÍA I	86	48	71	55,81%	67,61%				
MATEMÁTICAS BÁSICAS	102	46	71	45,10%	64,79%				
ELECTRÓNICA DIGITAL	94	34	79	36,17%	43,04%	máximo	60%	máximo	90%
COMPUTADORES	71	37	58	52,11%	63,79%	mínimo	26%	mínimo	43%
FUNDAMENTOS DE PROGRAMACIÓN II	129	34	67	26,36%	50,75%	MEDIA	45%	MEDIA	62%
FUNDAMENTOS FÍSICOS DE LA INGENIERÍA II	94	48	76	51,06%	63,16%				
MATEMÁTICAS I	108	65	72	60,19%	90,28%				

Figure 7: Fragment (in Spanish) of the summary of courses rates.

The responsible professors of the courses not getting the "expected results" are asked to present a report including the measures to be taken to overcome this situation. Making this information available for all the teaching staff makes the professors with low rates appear as the responsible of the consequences that not passing quality control may have.

A different question, pointing in the same direction comes from course syllabus. As degree contents must be approved by a national commission, they must include all the concepts considered as compulsory to let students get the competences associated to one particular degree. Besides, the detailed development of the syllabus is supervised by an institutional commission. In the case of the SITE degree, the quantity and complexity of the contents of almost every subject is quite ambitious, being this fact neither bad nor good. This situation becomes problematic when looking for minimum results in quality rates. Considering a first year physics course in an engineering degree, filled up with electromagnetism theory and semiconductor physics, it is easy to assume that the success rate can naturally be low. If someone finds the SR of a first semester Physics course to be almost 70%, can be that figure be considered more normal than, for instance, 30%? Besides, the average intellectual level and behaviour profile of the students can be (or will be) different from one year to another, including non controllable factors to the equation.

As a result of this environment it is possible to find two approaches. The first one includes those pretending to do their best (independently of one's capabilities) to help students get enough qualification. This attitude not always ensures getting the required figures of the quality program. Following the second approach, professors will relax the assessment procedures, so the final index will be as high as wanted, independently of the complexity of the subject. Choosing the second option the majority of first year students will be happy, and this attitude will be reflected in teachers' evaluation surveys, and institution managers will also be happy as quality rates overcome the limits. Possibly the only victim will be the real quality of the training programme. It is easy to agree that if one chooses the first option, the main injured will be her or himself. It would be necessary to include a reflection of the consequences one or another selection will have at long term, at both personal and institutional levels. I know well that this is a simplified vision of the situation, as this paper pretends to provoke reflection and debate. Even though, it must not differ much from reality in many situations.

Another aspect of the quality programs and the EHEA scenario affects methodology and assessment procedures. Even though we have been working for years with active learning schemes in last year courses with quite impressive results, the situation is different regarding first year ones and, specially, if the implicated teachers have not adopted the different methodologies as a personal option, but as an imposition. One of the major implications of the new model affects assessment including limitations to the maximum weighting factor applied to the final exam. The theoretical, and interesting, idea of promoting formative and continuous assessment has led a significant number of colleagues to program distributed partial exams during the semester and to obtain the final mark weighting different results. In my opinion this method is neither continuous nor formative assessment. To illustrate this fact, let us consider the following case. Figure 8 presents the marks histogram of a partial exam of a first year/first semester course, performed on October 2013. The marks are in the 0-10 scale, where 5 is the minimum result to pass the exam. This exam was made by a total of 69 students.

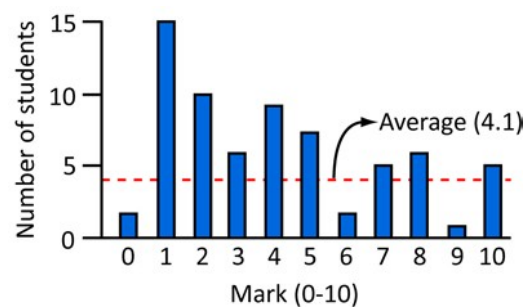


Figure 8: Marks after a partial exam in a first semester course.

Something is not working if 61% of students are failing one of the easiest exams of the semester, and 40% are getting a mark below 2 (out of 10). More over, the data displayed in Figure 8 is biased by students taking the course for a second time, who are the ones getting the higher marks. It is important to remember that we are suppose to be working with student centred methodology, with a very high level of individual tracking.

Let us consider another first semester course. This particular course also uses what is supposed to be a "continuous assessment" procedure, implemented as a series of partial exams distributed all along the semester. At the moment of the writing of this work, three exams have been evaluated. Figure 9 shows some of the results of the evaluation method in this particular course.

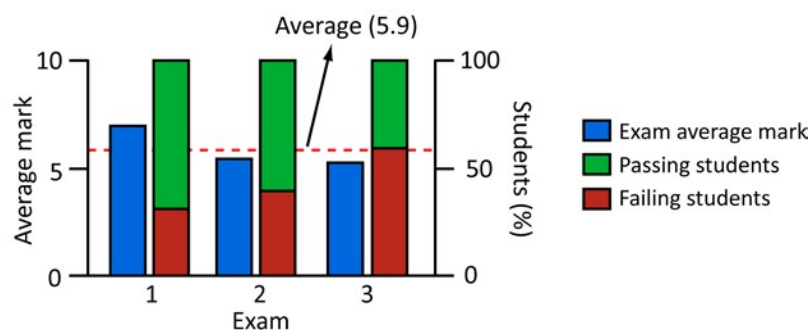


Figure 9: Results after three exams in a first semester course.

The nature of this course implies that students need previous knowledge as a basis to success with actual problems. Taking into account the decreasing tendency of the average mark and the number of passing students, it is clear that the concept of continuous assessment is not working properly.

It is remarkable that this behaviour can be extrapolated to almost all first year courses, but, curiously, the final rates obtained by the majority of them is high enough to meet the “quality” criteria, expressed in terms of the minimum effectiveness and success rates at the end of the semester.

I would like to notice, from my position as lecturer in first, third and fourth year courses, that our experience in higher courses is quite different. The work we have been doing adapting courses into active learning schemes is leading consistent good results, perfectly adapted to the new scenario. In this sense, I have also to admit our fault, as, though the institution does not cooperate in promoting a real quality model, we, as professors, have the faculty to adapt the way of doing to overcome the obstacles. Notwithstanding, first year courses implies a greater number of students per group and more teachers per course, most of them reluctant to change the way they have been working for years.

5 Conclusion

The Spanish university system is under a complex and well detailed quality control structure. It is evident that this fact, per se, is not bad. The problem arises when the quality model is finally structured in some compulsory methodological changes many teachers do not trust and a set of figures that all degrees must meet. These are, mainly, the institutional nightmares referred in the title of this work. Some details have been provided of how the quality control is implemented at our local area and at our university. One of the first conclusions is that, at least at bureaucratic level, the appearance that high quality standards are met is maintained. On the other side, a great responsibility falls on teachers, as they are who have to decide whether to act according to the system or not, assuming the implications, both personal and professional, this decision might have.

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The Continuous Challenge in teaching Engineering to Students from a Society with no Tradition for Higher Education

Hans Peter Christensen

Technical University of Denmark, Sisimiut, Greenland / Universidad de los Andes, Bogota, Colombia

Email: hapech@sanilin.gl

Abstract

The engineering programme in Arctic Technology from the Technical University of Denmark enrolls students from Greenland and Denmark. Since the Greenlandic students underperformed and had a high drop-out rate, several initiatives have been initiated to help the weak Greenlandic students. The results are analysed, and it is clear that even though the initiatives have proved popular, they have not fundamentally solved the problems in giving a higher education to young people from a society with a weak tradition for education.

Keywords: cultural differences, basic sciences, retention, adapted teaching

1 Introduction

Since 2001 the Technical University of Denmark (DTU) has offered a study programme in Arctic Engineering. The programme, which is supported by the government of Greenland, takes place partly in Greenland and partly in Denmark, and enrolls both Greenlandic and Danish students. There are two main objectives for this programme: 1) To educate professionals with a deep understanding of the Arctic and 2) To give the Greenlandic youth a better chance for getting a higher education.

The possibilities for taking a higher education at the University of Greenland 'Ilisimatusarfik' are limited and do not include the Sciences or Technology (www.ilisimatusarfik.gl), and it is a challenge to Greenlandic students to go abroad to study (Johnson, 2009). The Greenlandic students have a low retention rate, when they go to Denmark or elsewhere to take a higher education, even if it requires a higher grade average from high school to get financial support to study outside Greenland than in Greenland. It is difficult to get reliable data, but 192 Greenlandic students started a higher education in Denmark in 2005 & 06 and 86 students graduated 5 years later in 2010 & 11 giving a retention rate of 45%; the corresponding numbers for students studying in Greenland give a retention rate of 51% (www.stat.gl). To help the Greenlandic students to a better start, it was decided to turn the structure of the study programme in Arctic Technology somewhat upside down: To start the studies in Greenland with the arctic specialisation and then continue in Denmark with more standard engineering courses.

On the surface this strategy seemed to work – the retention rate for Arctic Technology was approaching the average at DTU. The teachers felt however that the Greenlandic students had many problems, and a closer examination revealed that the Greenlandic students underperformed and had a much higher dropout rate than the Danish students in the programme. Several reasons can be given for this (Kahlig & Banerjee, 2007), and a number of initiatives have been taken to help the Greenlandic students. In many ways they have been successful, but they have not fundamentally solved the problems involved in giving a higher education to students from a newly developed society with a weak tradition for education.

In this paper the Greenlandic students' background is first discussed, and a brief summary of the structure of the engineering programme in Arctic Technology is given. Then some initiatives to increase the number of Greenlandic graduates are described followed by some statistical data, and finally the results are discussed and some conclusions drawn.

2 The Greenlandic student

The small Arctic Greenlandic society, which, with a population of only approximately 56.000, is part of the Danish Kingdom, is now a modern society with Self Rule, but only half a century ago it was primarily a fisher and hunter society governed as a colony by a Danish elite. But in many ways it is different from other former colonies. The living standard in the urban areas, where most people live, is relatively high, with high salaries and high costs of living. Approximately half the national budget is supplied from Denmark. The population is a mixture of the indigenous Greenlandic

Inuit population and Europeans (mostly Danish) with no clear division between the groups. But in some ways Greenland also have many societal problems like other new democracies.

It is difficult to run the primary and secondary school systems in Greenland due to the structural and logistic problems, when very few people are spread over an enormous area with very limited infrastructure. From high school or even earlier students have to live on boarding schools seeing their family only a few times a year – and family means a lot to Greenlandic people.

There is sufficient money to support an efficient educational system; EU is earmarking a large part of the money paid for fishing rights in Greenlandic Waters to education – the problem is to get it to work. The first Greenlandic higher educational institution was a school to educate teachers (and local priests). Still there are not enough practicing Greenlandic teachers to give Greenlandic children a good primary school experience. The Greenlandic high schools, which until a year ago were a copy of the Danish school system, are almost exclusively taught by Danish teachers – and even if Danish is taught to Greenlandic children from a young age, the native non Indo-European Inuit language is so far from Danish that many students master Danish at a rather rudimentary level. And the cultural background embedded in the Greenlandic language makes it very difficult to comprehend topics at an abstract level.

It is very difficult to learn at university what you should have learned in high school, and it is very difficult to learn in high school what you should have learned in primary school – and even if you get good high school grades, you may have big problems with basic knowledge not tested in high school.

On the surface Greenlandic students act very much like European students, but below the surface the cultural roots sinks deep resulting in a very unpredictable behaviour from a western cultural viewpoint. Up to 50 % drops out of high school, and those graduating have often unsuitable study habits for a higher education. The students going to university are the good students, which have never experienced serious consequences of erratic behaviour and not doing their school work, so when they face this in higher education, it comes as a surprise to them, and for many it takes (too) long to adopt to this situation.

3 The Engineering programme in Arctic Technology

The professional bachelor programme in Arctic Engineering is unique in several ways: The students start their education in Greenland in the small city of Sisimiut with a population of approximately 3000 and finish it at the large DTU Lyngby campus in Copenhagen. The students are a mixture of Greenlanders and Danes, and the teaching structure of the first three semesters in Greenland is organized quite different from the norm at DTU in Denmark. Almost all teachers live in Denmark and travel to Greenland to teach full time for one to three weeks, and then a new teacher arrives to teach new topics. This means that the students at any time only have one course, which is finished and evaluated before the next start (in contrast to the situation at DTU in Denmark, where they can have up to six courses in parallel, and most are evaluated at the end of the semester). As a consequence of this the students tend to spend much time in class.

4 Initiatives to increase the number of Greenlandic graduates

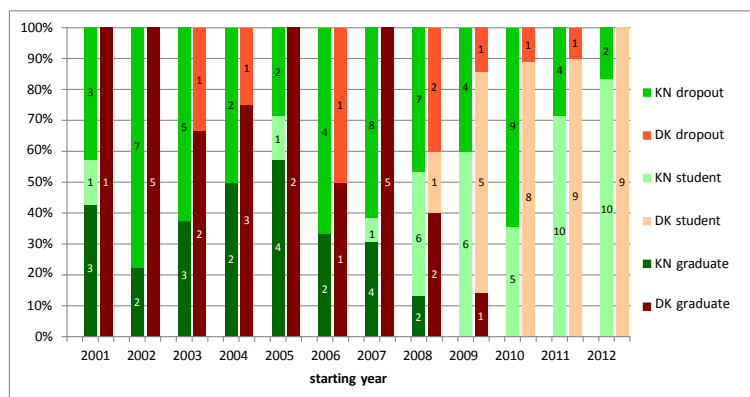


Figure 1: Statistics for Greenlandic (KN – the green bars at the left) and Danish (DK – the red bars at the right) students at Arctic Technology. Dark colours at the bottom indicate graduated engineers. Light colours in the middle indicate students still active. Medium colours at the top indicate students that have dropped out.

4.1 The problems

After the first five years of the programme it was clear that something had to be done, if the programme was not to be closed down. Two problems had to be attended:

- 1) The enrolment in the programme was insufficient; it had dropped to 8-9 students each year of which 5-7 were from Greenland.
- 2) Too many Greenlandic students dropped out as indicated in Figure 1, and many of those who remained underperformed. The accumulated retention rate for students starting 2001-2007 is 43% for Greenlandic students and 86% for Danish.

4.2 The remedies

4.2.1 The new curriculum

In 2007 it was decided to change the curriculum structure from a theoretical to a practical active-learning approach. The curriculum was reorganised from single-subject courses into large interdisciplinary courses with intercultural group work based on authentic local cases – called composite courses (Christensen, 2008; Ingeman-Nielsen & Christensen, 2011). This change can be argued based on general learning theory (Brandsford et al., 2000), but it was also an attempt to introduce a teaching philosophy more aligned with the Greenlandic students' cultural background (Hoffmann et al., 2011).

The active learning was enforced via the overall structure, which assured the active participation of the students. The teachers were not required to use any specific teaching methodology, since different methods may work in different situations. Brandsford et al. (2000 p. 22) writes "Asking which teaching technique is best is analogous to asking which tool is best - a hammer, a screwdriver, a knife, or pliers. ... There is no universal best teaching practice." Per Fibæk Laursen (2004) calls this the principle of *non-specificity* in teaching. It is not the methods or techniques that are of critical importance for student learning, but the way you use them. And teachers going to Greenland to teach are very dedicated teachers, so they develop their own best practice.

The change was a success. The enrolment increased dramatic; it tripled from 2007 to 2010. The students were happy with the practical approach in the composite courses. And the teachers were happy because the students showed up to classes and participated actively in the activities.

This success however also introduced some problems, since more Greenlandic students with weak preconditions for a university study were enrolled.

4.2.2 The retention project

Together with the new curriculum, a project (Fastholdelse gennem Øget StudieKompetence – Retention through enhanced Study Competence) to limit the dropout rate funded by the Greenland Government (as part of an initiative to increase retention in the Greenlandic educational system in general) was started up. The project included a theoretical part to inquire into why the students dropped out of the programme and a practical part including a coach to support the students in Greenland.

The project was a success in creating a class in Greenland that was socially strong and seemed well prepared for the study in Denmark. Much to the despair of the teachers and the coach, however, the class completely disintegrated when transferred to Denmark, with an average pass in the first semester in Denmark of 1.3 courses out of 5 for the Greenlandic students (the Danish Arctic Technology students in the class passed in average 4.8 courses).

It is an enormous challenge to the Greenlandic students to adapt at the same time both to the living in a big city and the independent study at a big university (there are more students at the DTU Lyngby campus than there are people in Sisimiut – and the area of the Lyngby campus is comparable to the area of Sisimiut).

Something had to be done, and it was decided to implement two changes in the strategy:

- 1) The focus should still be on giving the Greenlandic students a good start. But since the study includes a transfer to Denmark, it was equally important to prepare the students for the much different life at the big campus in Lyngby, where much more independent work is required.

Studying in the small strongly supported environment in Sisimiut is not the best preparation for the Danish campus. Therefore the close support of the students should decrease at the second semester and stop at the third semester, so those not capable of studying on their own, would not be transferred to Denmark – almost inverting the original

strategy of trying to keep as many students as possible in the programme. It is better for all that a student stops in Sisimiut, than s/he is transferred to Denmark and is faced with a fiasco there.

2) The focus of the coaching was shifted to Lyngby, so the Greenlandic students have access to a coach especially at the first semester in Lyngby. And the Arctic Technology Centre in Lyngby set up an incoming programme to welcome the arctic students, right from when they land in the airport.

4.2.3 Language support

Most Greenlandic students without at least one Danish speaking parent or without spending 10th grade at a Danish boarding school have severe problems with the Danish language – how much this influence the student's performance and what to do about it is a continuing topic for debate in the teacher group.

Several approaches to help improve language skills have been tried out. The main problem is that only few students are willing to admit that they have a problem, so volunteer classes in Danish have not been an overwhelming success. Another approach has been to require students, who hand in written assignment in bad language, to rewrite the assignment with the help of a Danish language teacher – the difficulty with this approach is to get the course teacher to focus on the language and not only on the content.

The bad news is that all students, who have had language support since 2007, eventually all have dropped out.

4.2.4 Individual Math-Physics remedy plans

At the Arctic Engineering Students Challenge Workshop in Sisimiut 2010 (Boffil et al., 2010) it was suggested to make individual remedy plans for each student – and since Math and Physics are the big challenges for many of the Greenlandic students due to missing competences from primary and secondary school, it was decided to focus on these topics.

The first course in Math and Physics is given at the second semester, but already at the beginning of the first semester, the students were given an entry test in Math and Physics. After the test individual remedy plans were set up for each student specifying weekly assignments in different topics, which the student should hand in during the first semester. A teaching assistant was assigned to help them and give feedback.

The students like this chance to get a good start in the Math and Physics course; more students than have to attend the teaching assistant's classes. And the teacher saves time in the course, since you don't feel obliged to do any repetition of high school topics.

5 Statistical data

5.1 The years 2007-2010

The average grade for the first 3 semesters for students enrolled 2007-2010 is presented for respectively 39 Greenlandic (KN) and 24 Danish (DK) students in Figure 2.

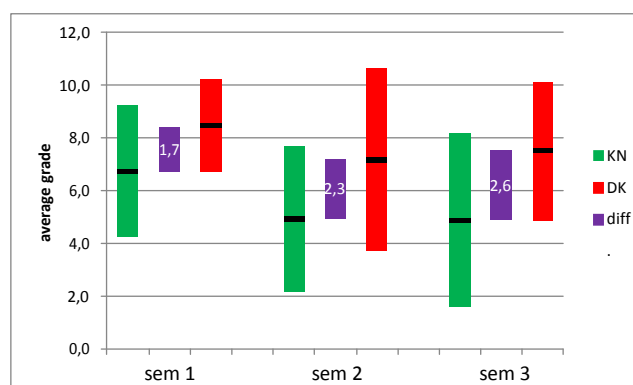


Figure 2: Average grades with standard deviation for courses at the first 3 semesters respectively of Arctic Technology for Greenlandic (KN) and Danish (DK) students starting 2007-2010. The small bars with numbers indicate the difference between average grades for Greenlandic and Danish students.

The Greenlandic students have lower average grades. Unfortunately the difference between Greenlandic and Danish students grows from the first to the third semester; the second semester has the more mathematical challenging courses, so a drop for both groups are not surprising, but where Danish students recover a little at the third semester, the average for Greenlandic students continues to decrease. It could have been hoped that the difference between different student groups would level out.

5.2 Students starting year 2010

23 students started September 2010; 14 students from Greenland and 9 students from Denmark. 5 Greenlandic students dropped out during 1st and 2nd semester.

In addition to passing a high school exam, the students must pass the following courses in order to enrol in the Engineering Programme in Arctic Technology: Mathematics A (high level), Physics B (medium level) and Chemistry C (low level). The Danish grading scale goes from 12 (A) to –3 (F) with 02 (E) as the minimum grade to pass and 7 (C) as the average grade.

In Figure 3 the average grades for students for the first 3 semesters are plotted as function of their M4P2F1 high school grade, which is calculated with a weight of 4/7 for Mathematics, 2/7 for Physics and 1/7 for Chemistry.

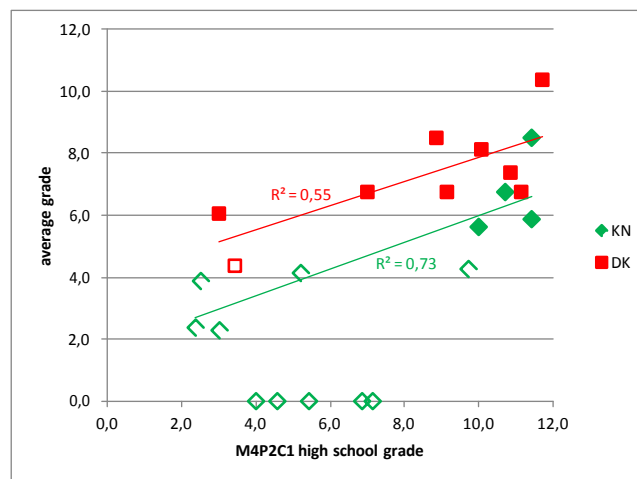


Figure 3: Average grades for the first 1½ year of Arctic Technology for Greenlandic (KN) and Danish (DK) students starting 2010 as function of their M4P2C1 high school grade. Students dropped out have been given the average grade 0. Closed symbols indicate students who passed all courses.

There is a good positive correlation between the average grade the first 3 semesters and the M4P2C1 grade for each student group (student dropped out not included), but the linear regression line is approximately 2 points lower for Greenlandic students than for Danish.

No Greenlandic student with a M4P2C1 high school grade below 10 (B) has passed all courses at the first three semesters in Greenland, which is required for being transferred to Denmark for continued studies.

3 of the 5 Greenlandic students who did not pass all courses have later dropped out, and the two remaining had 1 year later not yet been transferred to Denmark.

5.3 The course Mathematics in Physics

The integrated course Mathematics in Physics is the students' first course in math and physics. The course has a total length of 6 weeks full time study.

5.3.1 Entry test

The students score in the entry test is given in Figure 4 versus the MathPhys high school grade based on 75 % Mathematic grade and 25 % Physics grade, which are approximately the weights of the two subjects in the entry test and in the Mathematics in Physics course.

There is a relatively good positive correlation between the students' entry test score and their MathPhys grade for the Greenlandic, whereas there is a much higher spread for the Danish students.

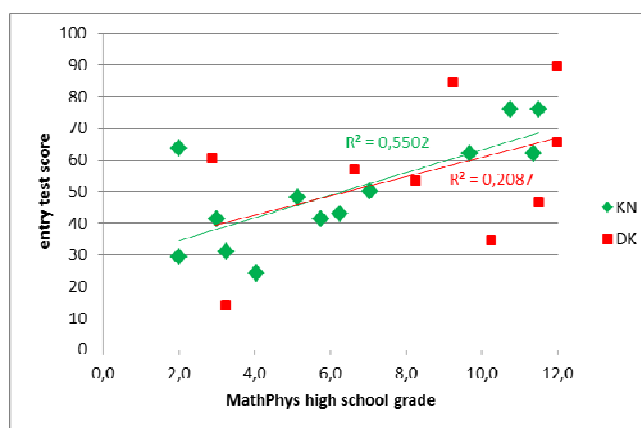


Figure 4: Entry test score as function of the MathPhys high school grade

After the remedy programme the test was given again. The Danish students participated in average more in the remedy programme than the Greenlandic students, but the Greenlandic students increased their average test score much more than the Danish. The test was given once more after the course Mathematics in Physics. The average score in the different topics are shown in Figure 5 for the Greenlandic and Danish students still in the programme at the end of the course.

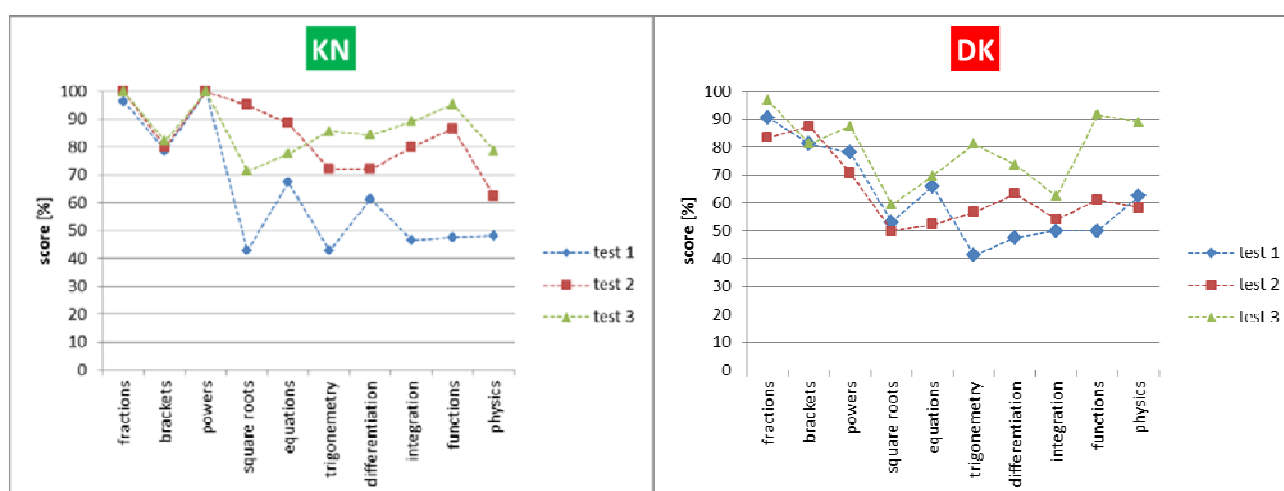


Figure 5: Average entry test scores for the different topics in the entry test for Greenlandic (KN) and Danish (DK) students for the three times the test was given. Test 1 was given in the beginning of the 1st semester, test 2 at the end of the semester after the remedy programme and test 3 was given at the end of the Mathematics in Physics course at the 2nd semester.

There is a very large spread on student performance in the different topics. The Greenlandic students apparently have had a good drill in fractions and powers, but had troubles with the fundamental roles of brackets in mathematical expressions – and this did not improve. Both groups have significant difficulties with square roots, and there is no significant improvement; the Greenlandic students scored high on square roots in test two but did not in test three. The Danish students had no improvements in the first 5 very basic topics – what you don't have learned in primary and secondary school is very hard to come after in further education. The improvements in the less basic topics are more clear – especially for the Greenlandic students.

5.3.2 Study habits

The students were asked to register their study activity for each half hour 24 hours a day 7 days a week during the Mathematics in Physics course.

The students average study load was 33 ± 9 hours/week. This is comparable, to what has been obtained in previous investigations at DTU (Christensen et al., 2009), but less, than have been reported elsewhere (Christensen, Gras-Martí & Ávila Bernal, 2012). Compared to an expected DTU weekly study load of min. 40 hours the students in average studied at 82 % of the norm with a few over the expectancy. The average distribution between different activities (attend-

ing class, doing assignments at home (there was an assignment almost every day) and reading theory) is given Figure 6.

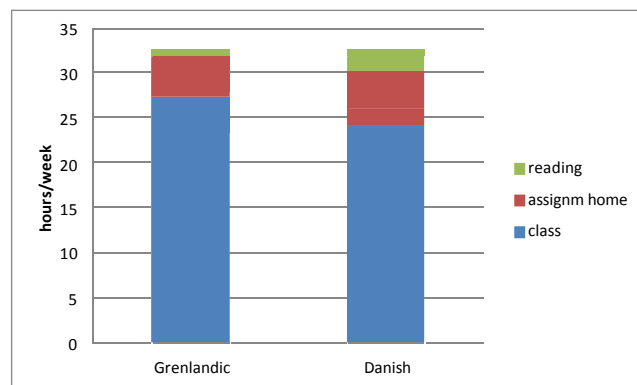


Figure 6: Total study time and distribution of time spent on different study activities for Greenlandic and Danish students

There is not any significant difference in total study load between Greenlandic and Danish students (average 33.1 compared to average 32.4), but there is a clear difference in the way they study. Greenlandic students spend in average more time in class and spend in average only half as much time reading as their Danish colleagues – but there is a big spread; the min and max values are almost equal for the two groups.

There was no difference in the average number of assignments handed in by the two groups.

5.3.3 Exam

The exam in the course consists of two parts: A 1-hour conceptual test and a 1½-day assignment, and both parts must be passed in order to pass the exam. 6 students failed the exam (3 Greenlandic and 3 Danish).

There is a good positive correlation between the average exam score and the entry level defined as the average between the MathPhys high school grade and entry test 1 score as shown for the two groups in Figure 7 – the good students at the beginning is still the good students at the end of the course.

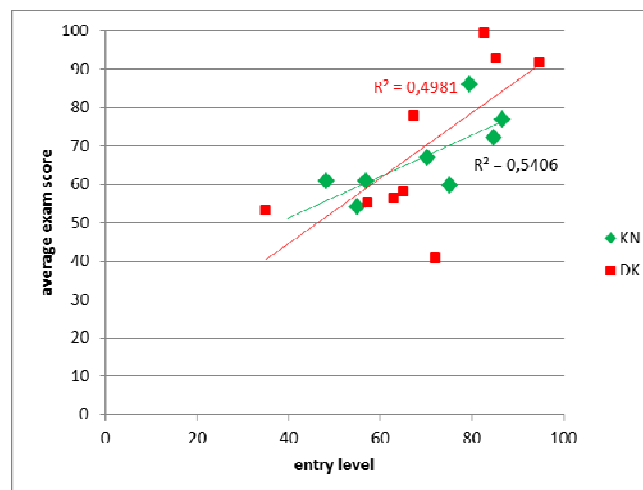


Figure 7: Average exam score in the course Math in Physics as function of entry level for Greenlandic (KN) and Danish (DK) students

There was no overall correlation between average exam score and neither total study load or study strategy, but the score in the 1½-day assignment had a good correlation with study load for the Greenlandic students as shown in Figure 8, whereas there was no correlation for the Danish students.

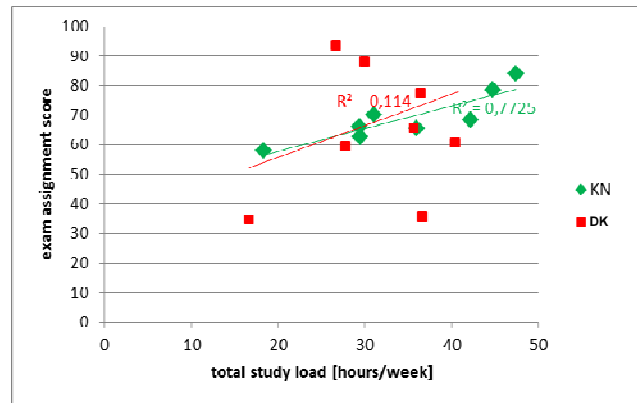


Figure 8: Score in the 1½-day exam assignment versus total study load for Greenlandic (KN) and Danish (DK) students

6 Discussion and conclusions

Greenlandic students underperform, and relatively more Greenlandic than Danish students drop out of the engineering education in Arctic Technology. One obvious reason for this is that in average the Greenlandic students come with lower high school grades (M4P2K1 = 7.4) than the Danish Students (M4P2k1=8.4; mostly due to higher grades in Physics).

But this cannot be the whole explanation. When comparing the Greenlandic and Danish students starting in the years 2007 to 2010 (Figure 2) the difference between Greenlandic and Danish students grow during the three semesters while still in Greenland indicating that Danish students seem to adopt better to university studies than Greenlandic. One reason for this could be that the students are required to be more independent at the third semester and Greenlandic students don't handle this well.

And as seen from Figure 3 a Greenlandic student starting in 2010 with the same M4P2K1 high school grade as a Danish student is likely to get a two point lower grade in average over the three first semesters – even when those dropped out are excluded. This could be that Greenlandic high school grades are inflated, but they use the same exam questions and external examiners as in Denmark, and when tested in Math and Physics at the start of the programme, there was no difference between Greenlandic and Danish students (both groups scored 56% in average). Another explanation for this could be that often Greenlandic students also have a language problem, and a language problem becomes very serious at university level, when you have to read and understand texts and not just follow procedures.

The high school grades seem to be valid (Figure 4) and these grades seem to have more influence on grades than total study load or study habits. It is possible that a high study load can improve a student's skills in problem solving for students depending more on following learned procedures than independent problem solving as indicated for Greenlandic students in Figure 6. But study habits seem not correlated with conceptual understanding.

The welcome programme in Lyngby has not been a full success, because the Greenlandic students have not fully used the offerings from the coach. The Greenlandic students apparently don't see a need for special help before it is more or less too late. Workshops on how to study efficiently have been attended mostly by Danish students or been cancelled due to too few participants.

6.1 Conclusions

The average retention rate of 43% for Greenlandic students of the first 8 classes of Arctic Technology is comparable to that for Greenlandic students starting their university study in Denmark. However, a higher high school grade average is required to get Greenlandic financial support to study outside Greenland than to study Arctic Technology, which in this respect is considered a Greenlandic education, so students with lower grades are admitted, even though they have to do most of their study outside Greenland.

Many Greenlandic students enrol in the Arctic Technology programme because they cannot get the education they really want, or because they don't know what they want, and then they try out Arctic Technology because it is right there in Greenland. This does not create the highest motivation, and will lead to somebody that could graduate will leave for other studies. And because the study starts in Greenland, many excellent students choose another study, because they want to try the world outside the small Greenlandic society.

With the present intake of students, where many have low motivation and very low grades in Math and Physics from high school, it does not seem likely – and maybe not even desirable – to increase the retention rate for Greenlandic students significantly. It is not possible in a demanding and intensive engineering programme to help students with missing basic competences in basic sciences or language from primary and secondary school to catch up on 10 years of neglect – this deficit cannot be mended by classes and tutoring offered in addition to the normal courses.

If it will not be possible to increase the admission requirements to language skills and basic competences in the sciences, it is important to stop the students without any chance for graduation during the first three semesters in Sisimiut, before they are transferred to Denmark. Focus in the future should therefore be on helping the clever but underperforming middle group of Greenlandic students to obtain good study habits, so they can overcome the problems with their cultural-related weak preconditions for a university study.

After the introduction of the welcome programme in Lyngby and more focus on stopping the very weak students in Sisimiut a beginning decrease in drop out in Lyngby can be expected, but the welcoming programme should be intensified. If the Greenlandic students don't come to the coach, the coach must come to the students, if a further decrease in drop-out rate in Denmark should be obtained.

But let's end on a positive note: More and more Greenlanders graduate as Arctic Engineers every year, and they go back to Greenland to work.

Acknowledgement

The author is grateful to the Facultad de Ingenieria at Universidad de los Andes for the support under a sabbatical that made this work possible.

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Engineering teaching practices in Colombia: what are they and what type of learning are they developing?

Amparo Camacho*, Adolfo Arenas**, Jorge Celis⁺, Mauricio Duque⁺⁺

*Universidad del Norte, Barranquilla, Colombia

**Universidad Industrial de Santander, Bucaramanga, Colombia

+Universidad Nacional de Colombia, Bogotá, Colombia

++Universidad de los Andes, Bogotá, Colombia

Email: acamacho@uninorte.edu.co, aleon@uis.edu.co, jecelisg@unal.edu.co, maduque@uniandes.edu.co

Abstract

Over the last two decades, ACOFI (Engineering school association of Colombia) and ICFES (Colombian Institute for Educational Evaluation) have been working together to develop the National Test (known as Saber Pro) whose focus is to assess the levels of competence acquired by engineering students. After some analyses, it has been found that teaching practices have an important influence on students' performance. On the other hand, in Colombia the dropout continues to be too high. Part of this problem seems to be related to the teaching practices that faculties are using in classroom. Some practices neither encourage students to learn nor develop those competences that have considered as fundamental to the future engineers in the time to come. In order to know what type of teaching practices are being applied by engineering faculties in Colombia, a national survey was conducted in 2013. Based on some previous similar studies done in EEUU, this survey was elaborated. This work presents some insights found in the analysis of the survey's results.

Keywords: Engineering teaching practices, assessment in engineering, generic competences assessment.

1 Introduction

Colombia has created a national evaluation system aimed at assessing the levels of competence of students who are at different educational levels ranging from primary and secondary education to higher education. The system assesses generic competences, such as critical reading, writing, and quantitative reasoning, and it makes possible to trace the levels of competence that students achieve over time. The system comprises three types of tests, known as Saber 3, Saber 5, Saber 9, Saber 11, and Saber Pro. The former is devoted to assessing the levels of competence of students being at primary level and the latter levels of those students being at higher education level.

Some analyses have shown that teaching practices applied by faculty to classrooms have a crucial influence on the levels of competence that students achieve in Saber Pro Test.

This paper presents firstly the levels of competences that engineering students achieved in Saber Pro Test in 2012. Students' levels are compared with those of students pursuing a bachelor degree in 5 different fields of study. Secondly, the paper discusses faculty' and students' perceptions on engineering teaching practices.

2 Results of SABER PRO test

This section makes a brief presentation of what generic competences are as well as the sections that comprise the Saber Pro test focused on assessing generic competences. Subsequently, it shows the levels of competences that engineering students achieved.

2.1 What are generic competences?

Tunning project (2013) mentions that there are three types of generic competences, known as instrumental, interpersonal, and systematic competences. Capllonch and Castejón (2007) assert that these competences comprise a set of cognitive, research, social, and technological skills. Instrumental competences permit students to understand ideas, organize time, share verbally and in the written way ideas with different individuals, define strategies to solve problems, manipulate information, and finally use machinery. On the other hand, interpersonal competences are essential for students to be able to express their own standpoints and work in team groups. Finally, systemic competences enable students to apply knowledge to specific situations and generate new ideas (Bath, Smith, Stein, and Swann 2004). Other taxonomies are proposed, like those quoted by Bath et al. (2004): critical thinking, problem

solving, interpersonal skills, logical skills and ability of independent thinking, communication and management information skills, intellectual curiosity and rigor, creativity, consciousness and ethical practice, just as integrity and tolerance.

2.2 SABER PRO test's evaluation sections

In ICFES (2013) the generic section of the test is presented. In next paragraphs there is a brief description on these components.

2.2.1 Writing section

This section assesses if students are capable of structuring, organizing, and communicating ideas in an effective way. Students have to write about a specific topic defined previously by ICFES. To write about the topics is not required specialized knowledge. A scale of assessment ranges from 1 to 8. 1 means that students are unable to communicate their own ideas on the topic while 8 means that students have the appropriate writing skills to produce a coherent text. Throughout intermediate levels, for example level 4 (a medium development text with basic structure but without complete information management, nor effective organization), are used to measure student's performance.

Being a cumulative scale, the accessing to a performance level involves overcoming previous level criteria. If the written exercise is not answered or it is incomprehensible, the test will be disregarded.

2.2.2 Quantitative reasoning section

This section assesses the competences related with skills in understanding basic concepts of mathematics to analyze, model and solve problems by applying quantitative methods and procedures based on the properties of numbers and math operations; and it will address issues related to:

- Interpretation: Understanding pieces of information, and the generation of diverse representations from them.
- Design and execution: Making processes related to problem identification, such as the definition of appropriate strategies to deal with a specific situation. Modeling entails using quantitative tools, such as arithmetic, metric, geometric, algebraic, probability and statistics.
- Argumentation: Justifying or refuting findings, hypotheses, or conclusions drawn from the interpretation and modeling of situations.

2.2.3 Critical Reading section

This section assesses the level of competence to link the discourses with the cultural practices that they involve and predetermine, which means the reader is able to get the deeper meaning of a text by recognizing the context in which it occurs and the discursive form it presents (ideological, textual, social). The assessment of this competence considers the capability to get explicit and implicit information from the text by reading and relating the information given.

2.2.4 Citizenship competence section

According to the ICFES, with this module it will be assessed the ability of students to participate, as citizens, in a constructive and active role in society.

Citizenship competences are part of the set of generic competences included in Saber Pro test. It refers to the training in generic competences, particularly in the civic ones; process that take place throughout the education cycle, from the preschool years to all subsequent education stages.

2.2.5 English section

This module relates to the competence to communicate effectively in English. This competence, in line with the Common European Framework (CEF) allows classifying examinees into four performance levels: A1, A2, B1, B2.

2.3 Engineering students' levels of competences

To illustrate the results obtained by engineering students in the generic test compared with the results obtained over other programs, some of which will be presented. The following results correspond to the 2012 national SABER PRO test.

2.3.1 General results

Figure 1 shows that engineering students obtain lower results than those of students from other programs, such as economy, medicine and basic sciences. The quantitative reasoning (QR) is the only competence in which engineering students get the similar level of competence to the rest of students.

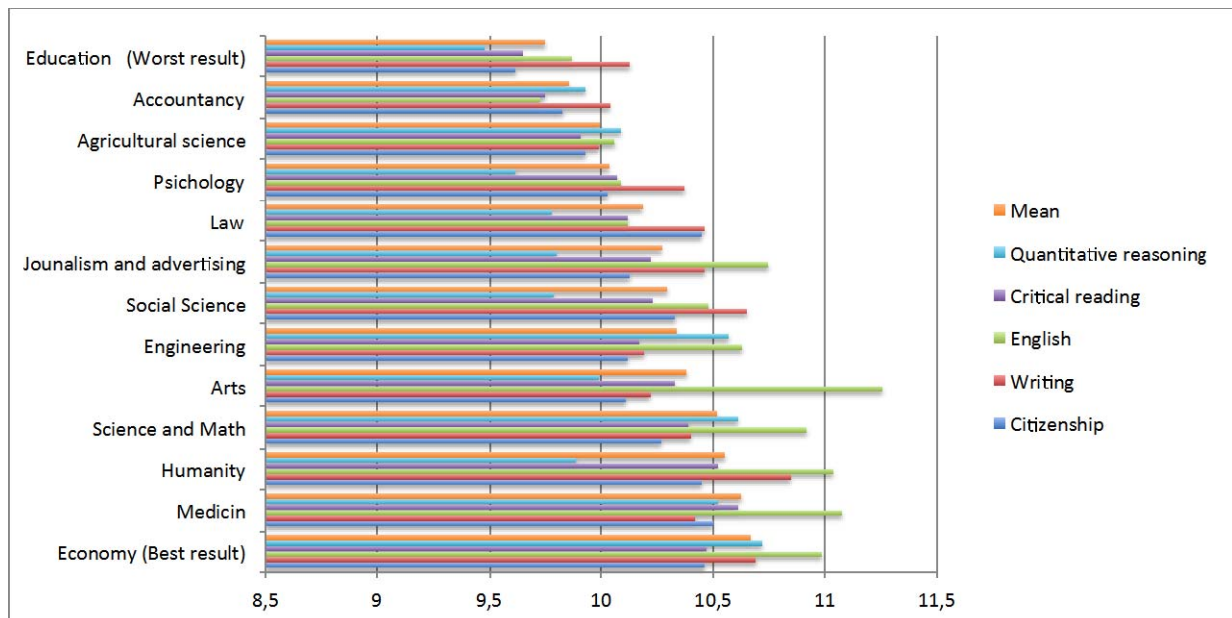


Figure 1: General results by module and discipline. Source: ICFES SABER PRO 2012

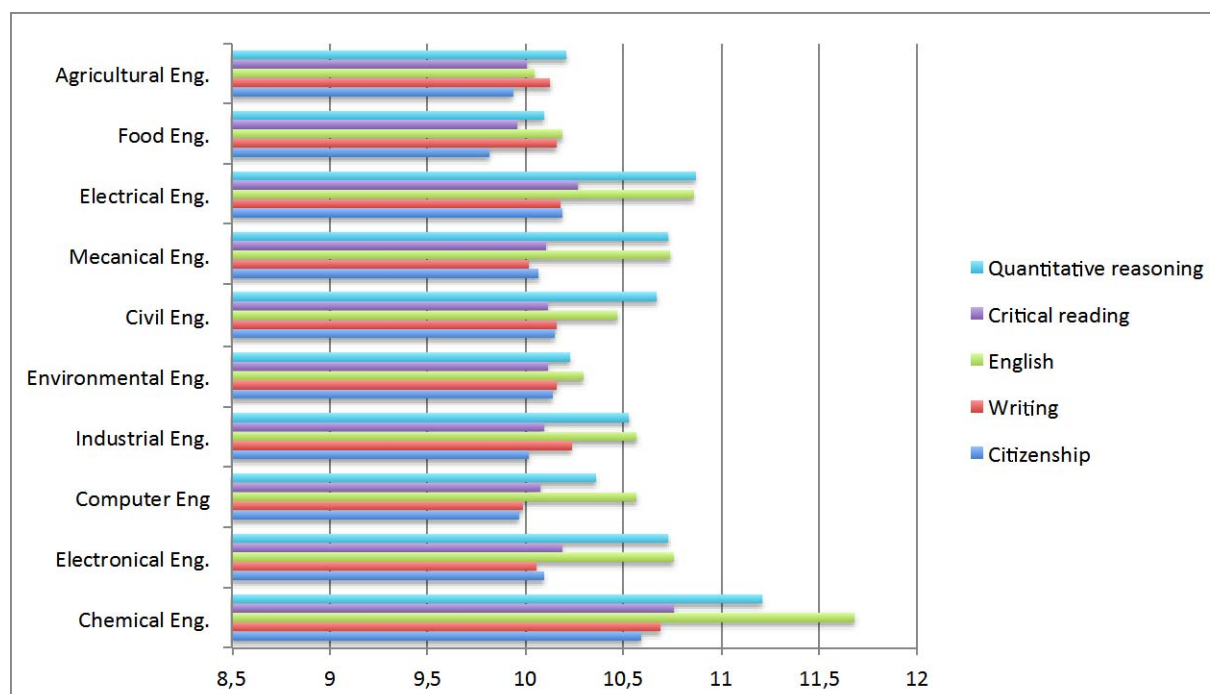


Figure 2: Results for different engineering programs. Source: ICFES SABER PRO 2012

Figure 2 shows the average results by modules and specialties within Engineering. The highest levels of competence are found in chemistry programs while the lowest are in food production and agriculture programs.

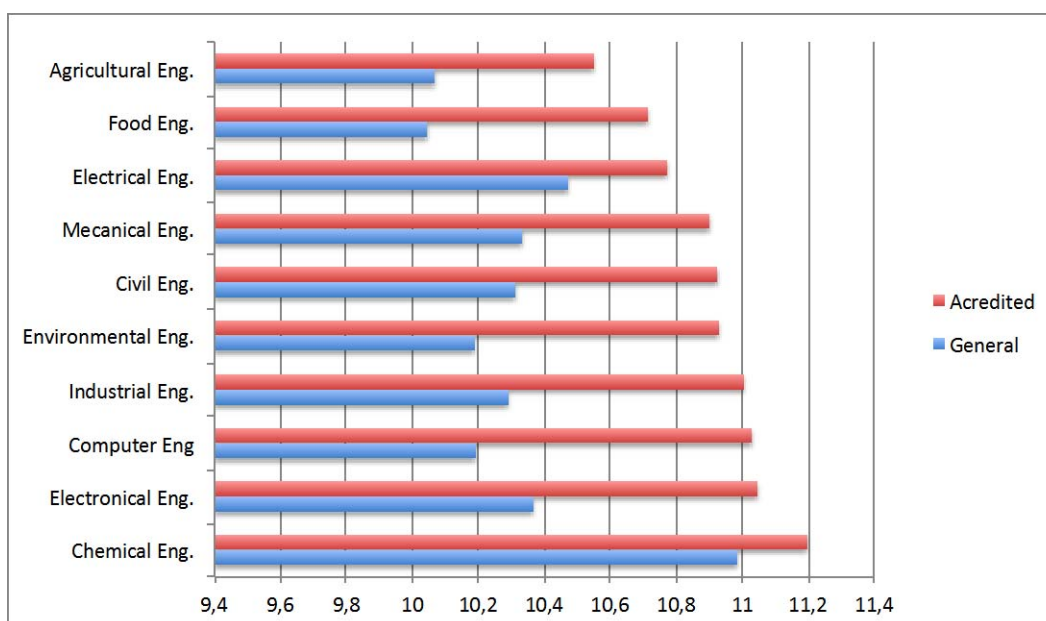


Figure 3: General result comparing accredited with non accredited universities

This last figure illustrates differences between accredited and non-accredited universities.

2.3.2 Results by module

Some components of the test include level definitions that allow a better pedagogical interpretation, those modules are: English, quantitative reasoning and writing.

This section shows the results of written communication module by performance levels. According to ICFES, the performance level is a qualitative description of students' competences in each module. It is expected that a person who is in a certain level demonstrate not only the competences related to it, but also the ones related to lower levels. In this module students are classified according to the 8-established performance levels.

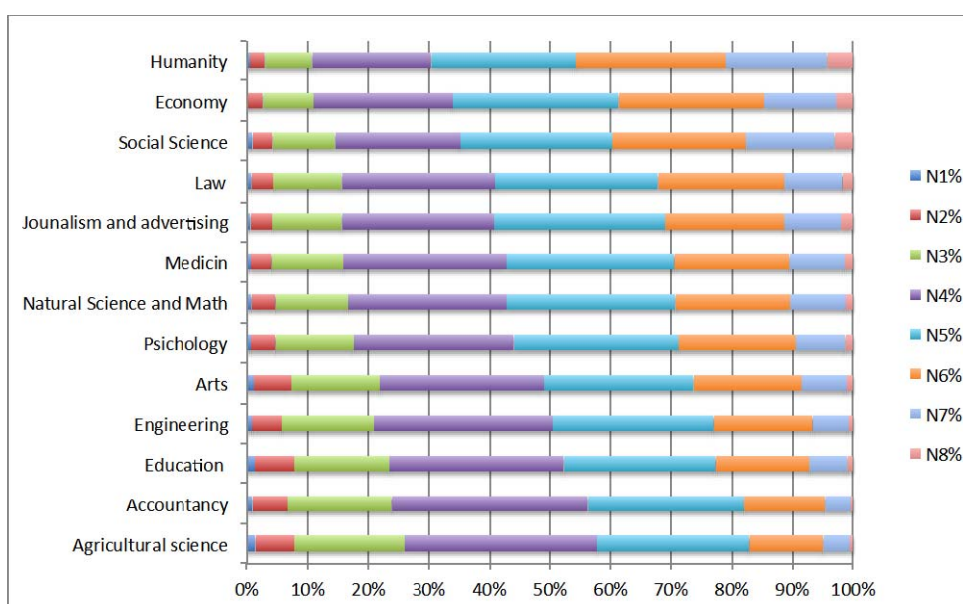


Figure 4: Test results relating to writing. Source: ICFES SABER PRO TEST 2012

In professional programs that scored a high performance in various modules such as medicine, more people are at higher levels compared to low-performing programs in several modules, such as careers in education. Approximately 50% of the population of engineering programs was at low performance levels.

2.4 Engineering design test structure

To assess the specific skills, common to all engineering programs in SABER PRO test, under the coordination of ACOFI, it was created an advisory committee, consisting of teachers from accredited universities and high-quality programs¹, responsible for making the framework and specifications of the modules making up the test. The framework and specifications were reviewed and adjusted with experts from different faculties of engineering and validated in face workshops with a large sample of engineering professors.

This framework included engineering design, as a dimension in assessing, recognizing the importance of design on the work of an engineer. There is an international consensus on the importance of design in the work of the engineer and the nature of this activity in engineering. Even though the engineer engaged in other activities such as developing research, plan, manage projects, build and operate, the design work is central activity that characterizes engineering (ACOFI, 2012).

The purpose of the test is to assess the "Competence to plan, design, optimize and develop systems, products or services. This will integrate knowledge and principles of basic sciences and engineering disciplines, in order to satisfy needs, requirements and technical, financial, market, environmental, social, ethical and economic restrictions" (ICFES, 2011).

Knowing that engineering design is a complex activity that integrates processes, capabilities and individual skills with social responsibility, it was proposed a simplified model of the design process, which includes three stages, denominated as components in the SABER PRO test:

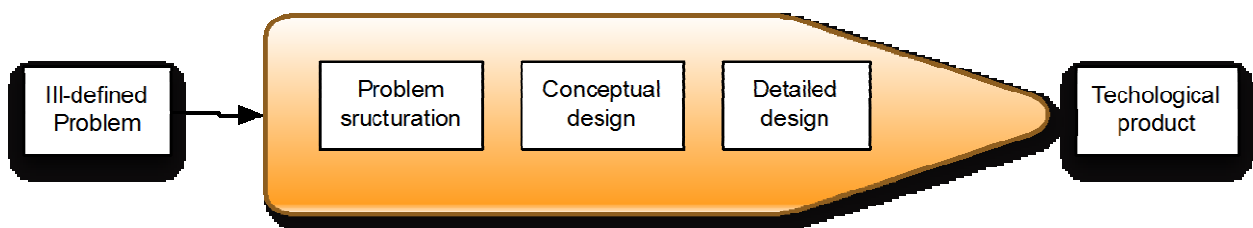


Figure 5: Engineering design conceptual view

Taking into account the three components in a basic process design, the purpose is to assess students' level of competence to know:

- 1) *Students' ability* to structure a design problem from a description of a realistic situation with incomplete, contradictory, excess and/or uncertain information.
- 2) *Students' ability* to make decisions and choose a solution among several potentially suitable possibilities, taking into account technical, economic, financial, social, environmental, and/or ethical criteria, from estimating and anticipating the impact of different alternative solutions.
- 3) *Students' ability* to use mathematics, science, technology and engineering sciences in the detailed specification of an artefact, process or system.

However, the only way to accurately assess the ability of an individual to design is to have him/her face a genuine design activity. The nearest alternative test, limited to multiple choice questions, was to set up design cases around which it was proposed a set of questions, taking as reference the College Learning Assessment (CLA), in order to make the student facing a situation a little more complex than the one created by loose and independent questions.

In a national survey were identified 9 possible contexts for the development of cases, which can cover most engineering designations, which exceed 100 in Colombia. The contexts identified are: mechanical systems, infrastructure works, production and logistics systems, industrial processes, agricultural systems, systems of prevention and management of environmental impacts; systems, processes and agro-industrial products, control systems and information management systems.

Experience showed that the construction of these cases represented a major challenge for the academic community. Additionally, the application of the test in 2012 showed that the cases given were difficult for most students, which had a negative impact on the reliability of the test. In a national survey with students who took the test in 2012 it was

¹ CNA: Comisión de acreditación Nacional de Colombia

found that the time given for the development of the test was not enough, the specific test in engineering is much more complex than the generic one, and that most of the answers were the result of different strategies to be able to develop the point (such as discard and random selection of the response).

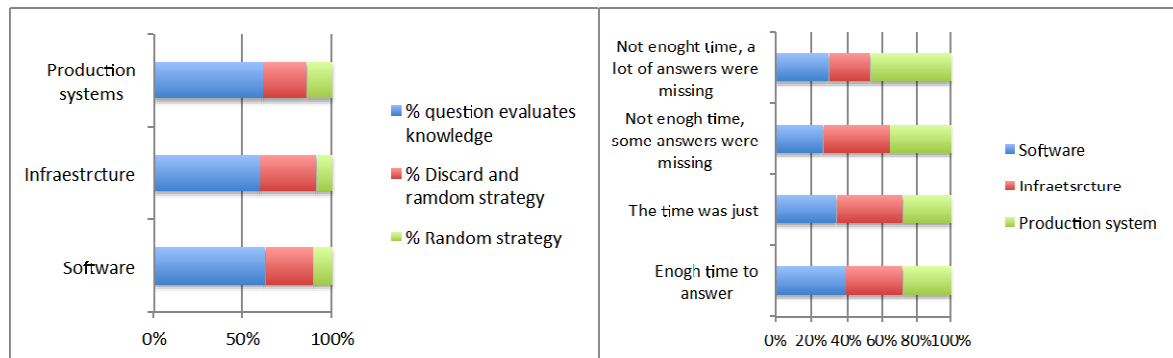


Figure 6: Strategy used to answer and difficulty. Source: Student national survey, ICFES-ACOFI

Main reasons for these results are:

- 1) Most of the students have just completed the 75% of their career, so they can only use skills that can be addressed in this first segment of the program, avoiding professional content that can only be addressed in the last year.
- 2) While students work in engineering design, apparently do so in a fragmented way; and at the time of the test they haven't been exposed to full and genuine problem solving design.
- 3) The length of the texts that introduce the different cases proposed is generally long and as shown in the critical reading test, many engineering students in Colombia have low performance on this skill.
- 4) Getting a lot of questions about an only case, which does not depend from one another, or keys to answer other questions, is a major challenge.

Consequently, the following adjustments were made to allow reliable results appropriated in the pilot implementation of 2013 and so to make easier the construction of cases:

- 1) Building cases by design components with fewer questions.
- 2) Reducing the complexity of some questions including loose questions.

Next figure shows improvement results across applications.

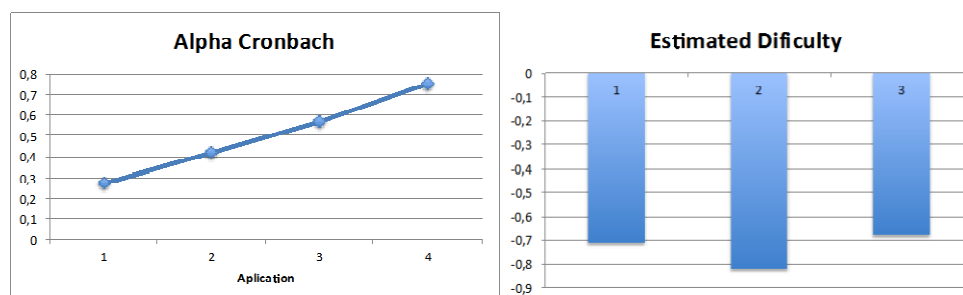


Figure 7: Reliability and estimated difficulty. Source: ICFES

Due the application of the test in engineering design is still implemented as a pilot, its results are not public.

3 Survey design

In order to describe teaching practices that are being carried out by engineering professors in Colombia, two national surveys were applied: the former addressed to faculty and the latter to students. The purpose was to make a comparison between faculty's and students' perceptions about classroom practices, keeping on mind what some actors appear as certainly is not perceived by others as such, and it is precisely that contrast which allows in some degree to know and characterize what is happening with classroom practices.

Students and faculty drawn from a database built by ACOFI were invited to answer two surveys during the month of July 2013. From 845 teachers that initiated the survey, only 729 (86%) filled out it effectively in its entirety. On the other hand, from 228 students, just the 84 per cent (197) did. 74% of the teachers and 57% of the students were male; 65% of teachers were working in a private university, while 56% of students were studying at a private university.

Fifty-five closed type questions were applied to teachers, while only 53 were given to students. Some of the subjects and questions were taken from a previously applied survey in the USA (Brawner, Felder, Allen, & Brent, 2011) and a work on professional development in engineering education in some Faculties of Engineering in Colombia (Duque, Celis, & Celis, 2011). These surveys asked about the attributes of quality teaching, the efforts to professionalize teaching in engineering, effects of actions aimed to professionalize teaching in the development of subjects, measurement of time of activities performed by the teacher to prepare the class, time quantification of activities performed by the teacher during class and finally, time quantification of activities performed by the teacher after class.

The survey taken by students, asked about some features of the lectures, the frequency in which certain activities are performed in lectures and laboratories, the frequency of some types of assessment relating to the development of classes, as well as the time spent by students to perform certain activities in and out of the class and the most common mechanisms used by students to contact teachers.

The surveys were validated through discussions among the authors of this document, some meetings with colleagues from other areas of engineering and the early versions required to fill out the survey. It is important to note that these surveys are the first of their kind in Colombia that are applied to the field of engineering in order to characterize teaching practices.

4 Results of the surveys

4.1 Main findings of faculty's survey

Teachers' perceptions agree that a quality teaching take place when:

1. Teachers design and assess students learning, have extensive experience and professional recognition and have the ability to teach in the real context of the professional practice of engineering.
2. Graduate students have received appropriate training to help undergraduate students in their academic difficulties through individual sessions or group monitoring practice.
3. The Schools of Engineering have adequate infrastructure, including laboratories and a good library for research in the discipline; and students can experiment with what they learned during the class.
4. The Schools of Engineering have a performance evaluation system of teachers in courses and students' positive results are contemplated.

The main activities carried out to professionalize teaching in engineering and that a significant number of teachers reported having used and perceived as useful are workshops, seminars and conferences that address issues associated with generic-type pedagogy.

The activities that teachers often use to prepare subjects are those related to the definition of educational goals, teaching activities based on experimentation and strategies aimed to help students with issues in which they have presented difficulties. It is important to note that the expertise of teachers to carry out these activities is the result of tradition or the teachers' own work, but not of the generic courses in pedagogy that they often receive. The above shows that classroom practices are the result of the experiences that teachers have acquired throughout his career more than the outcomes from a specific training (Shulman, 1987).

As for the activities that teachers engaged during the courses development, it was found that 24% of the time is spent in the presentation of the topic, and only 13% is used for designing tests to assess students (see Figure 7). But assuming that the activity related to solving the exercises is an activity performed by the teachers directly, 42% of class time corresponds to the presentations made by the teacher.

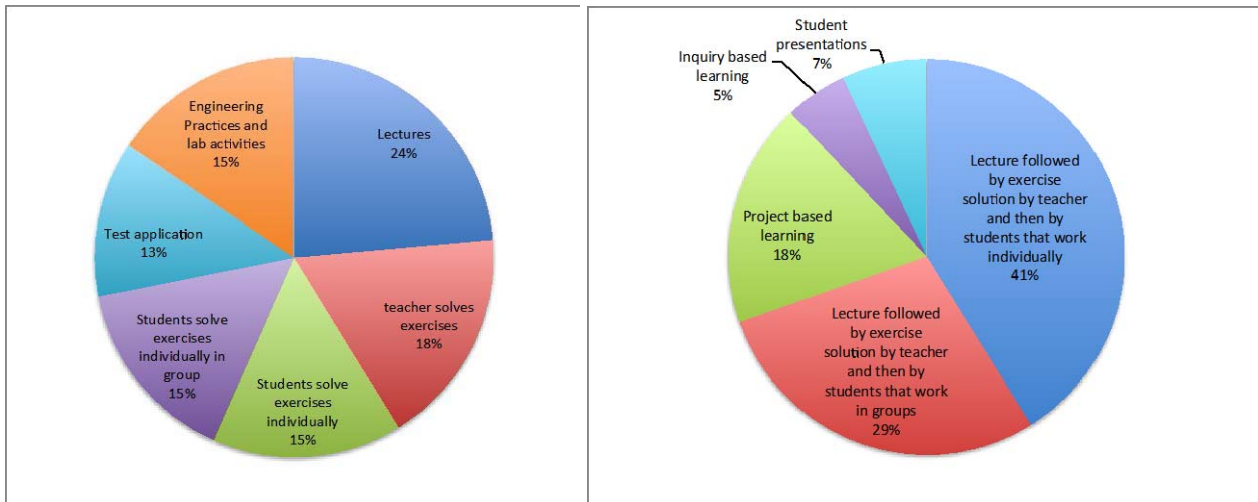


Figure 8: Classroom activities a) teachers and b) students. Source: ACOFI national teacher survey

About the after-class activities, teachers said that 51% of the time is directed to the attention of students, either in person or online, 32% to grade students works and exams, and only a 19% to conduct activities related to the administration of the academic system (uploading results, reports, etc.).

4.2 Main findings of students' survey

According to students' opinion, a typical lecture in engineering usually includes a presentation, by the teacher, of the issues, followed by a demonstration. This perception is consistent with the time spent by teachers presenting topics (see Figure 8-a) It is rare for teachers as part of their lectures, working on addressing specific phenomena.

Regarding the activities performed in the lectures, students mentioned that the most frequent activity is teamwork, while doing demonstrations with equipment or simulators and making technological designs to answer speculation are rarely done.

About laboratories, students agree that the most frequent activity is to use a laboratory guide that shows step by step what to do and record, while less frequent activity is one in which the guidelines do not indicate what data they have to take, or how to process (see Figure 8-b).

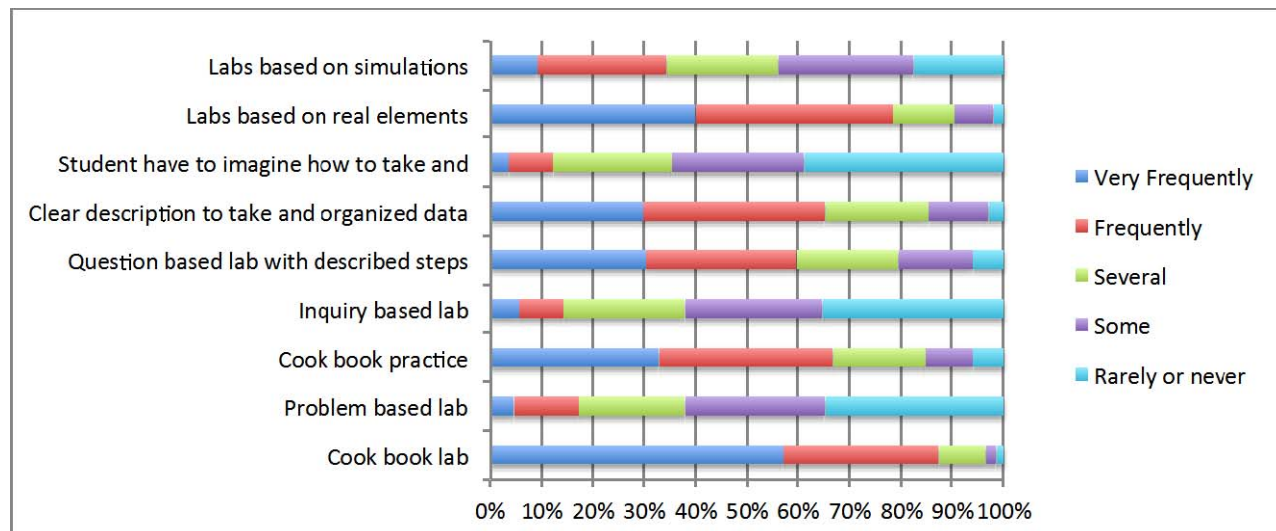


Figure 9: Laboratory function. Source: ACOFI national teacher survey

According to most students' opinion, generally assessments made by teachers are aimed at adding to the final grade for the course. Formative assessments, designed to enhance learning, are less frequent.

The 56% of students' time during the development of the course is spent listening to the lectures made by the teacher, which shows that the classroom practices are more focused on what the teacher does. Most of the after-classes students' time is intended to work on projects and tasks assigned by teachers.

Finally, email is the mechanism used by teachers to communicate with other teachers while the least used was the CHAT.

4.3 Faculty's and students' perceptions

- The majority of class time is devoted to presenting topics by faculty. It might be said that engineering programs' classes are as teachers do an exhibition and students just stare and listen.
- Although faculty believe that quality teaching should approach students to learn about the real context of the profession, students reported that classes are rarely supported by concrete phenomena. It is likely, though not made an inquiry about it, the engineering professor's profile is of an academic and professional experience in the field of engineering is rather absent in most teachers because it is considered important as such.
- Most of the time teachers spend after classes is aimed to address the concerns of students and the students also recognize this activity. One might think that although teachers do not engage in the activities that occur within the classes to assess or monitor students' learning process, the time spent after the class is one in which learning is discussed.
- Teachers recognized that laboratories are essential for quality teaching; by the way it was the only attribute in which a high consensus was recorded. However, labs are used most of the time for students to follow a laboratory guide through whom they develop and record activities once defined. The laboratories are not being used to solve problems or develop new inquiries into certain phenomena of interest to students.
- While teachers mentioned that an attribute of quality teaching is to design activities and to assess students' learning assessments, according to the students, are aimed at obtaining a final grade. There are not summative assessments or self-assessment by students. It is likely that teachers have the interest in the assessment, but their preparation and institutional resources do not allow them to carry out a type of evaluation, which really examines the process of the students' learning.

5 Conclusion

Assessment is undoubtedly a major challenge, with great benefits and risks (Assessment Reform Group, 2002a; Assessment Reform Group & Nuffield Foundation, 2002; Black & William, 2001).

The literature seems to be consistent by stating that learning assessment is pivotal, but faculty tend to rarely apply it to students' learning process (Assessment Reform Group, 2002b; National Research Council, 2003). The most frequent learning assessment used by faculty is summative assessment. These assessments are also essential in any educational process, particularly when the educational system must account for the powers for the exercise of a profession. As part of these assessments are standards, such as those advanced by the government of Colombia, in order to monitor the quality of education at different levels.

These first results of the application of the test SABER PRO show the need for improvements in the teaching-learning processes in universities as a significant number of students do poorly in several test components related to generic skills fundamental to the work, such as quantitative reasoning to a lesser extent. Critical reading, writing and English are between the most challenging.

In the engineering design test, as indicated, results are not yet public. It is known that the test generally has been difficult for students, as mentioned.

In comparing these results with the reported teaching styles in a national survey, it can be explained by the use of traditional strategies more focused on certain content and skills covered in a rather contextualized. It is rarely in the context of genuine design projects, for instance.

Taking into account findings related to the effectiveness of a classroom teacher (Kreber, 2013; Nicholls, 2002; Shulman, 1987, 2004) there are required training strategies in teaching engineering professors from new paradigms away from workshops and generic conference on the subject, to address more directly what it means to teach and learn in engineering.

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Actions on First Term Disciplines Aiming to Decrease Dropout Rate of the Computer Engineering Course

Fabiana Costa Guedes*, Lilian Barros Pereira Campos+, Rodrigo Aparecido da Silva Braga**

*, +, ** Federal University of Itajubá, Itabira Campus, Itabira, MG, Brazil

*, **Computing Applied to Engineering Research Group

+ Development, Society, Education and Culture Research Group

Email: fabiana.costaguedes@unifei.edu.br, liliancampos@unifei.edu.br, rodrigobraga@unifei.edu.br

Abstract

This paper reports the results of experiments on active learning methodologies (ALM) with first term students of the computer engineering course at the Federal University of Itajubá, Itabira Campus-Minas Gerais. After discoursing on some aspects of the ALM applied to engineering education and speaking of the implications of dropout in higher education, we present the activities conducted and their outcomes. It was possible to identify that the activities were effective for placing students in an active role in constructing knowledge anticipating vocational contents of the course. Furthermore, attitudinal skills were also worked on. All these aspects were mentioned by students as critical to enhancing motivation to remain in the course.

Keywords: dropout, active learning methodologies, Computer Engineering.

1 Introduction

The Itabira Campus of the Federal University of Itajubá was created from a public-private partnership between Vale S.A., responsible for laboratory equipment; the City of Itabira, responsible for the construction of buildings and infrastructure and the Federal Government, responsible for the maintenance and payment of personnel. The campus is five years old, with nine graduation courses under implementation. One of the existing courses is Computer Engineering with an annual intake of 50 students and a curricular structure of five years duration. Today, the course has five students graduated. The course dropout rate is 34.36% according to dropout calculations proposed by the MEC Committee described in Adachi (2009).

According to Boero and Silva (2006), students have their expectations frustrated with respect to university life, the academic methodology and excessive theoretical classes in the early years. In addition, they have little knowledge of the profession they chose to follow. What may explain the numbers presented. In a survey conducted among students that dropped out of the course in the last five years, the following reasons for dropout were reported: students consider the computer engineering course too difficult; the fact that the university is in implementation generates preference for longer established institutions; course entrance through the SisU (Sistema de Seleção Unificada - Unified Selection System) allows students to be admitted to courses that was not their first choice; some students are admitted at Itabira aiming to go to the main campus in Itajubá via internal transfer; there are reports that the demotivation is due to the fact that, at the beginning of the course, only basic disciplines are offered and that vocational disciplines are only taught at the end.

Several actions are being carried out in the institution in order to decrease dropout and retention rates, aiming to tackle the causes raised. In addition to actions to change the curricular structure and development of projects within the course, actions were taken on the discipline BACi01 - Science, Technology and Society - in which the introductory engineering content is taught. The actions taken were based on active learning methodologies that are the focus of this paper.

The following activities / active learning methods have been implemented: Ball-bearing Carts Championship - 3rd Edition: project-based learning; Computational Projects: project-based learning; Posters Dynamics (THIAGARAJAN, 2008): write-pair-share and discussion in class; Museum Dynamics: search-group-share and discussion in class; Electronics Laboratory Activity: problem-based learning. Dialogue based lecture classes: dialogue based classes.

This paper is divided into seven parts, including this introduction. The next section discusses the use of ALMs in engineering courses in Brazil. After this discussion, dropout and retention aspects are placed in the same context. After, we describe the Unifei Itabira situation. Thus, we explain the actions taken and their results with respect to the achievement of the objectives proposed. Finally, discussions on the data and final remarks are presented.

2 Active learning methodologies applied to engineering education

The last decades have been fruitful regarding the discussion of active learning methodologies (ALM) in the context of engineering education. Globally, there have been discussions and references for teaching and learning that have been seeking to innovate the teaching in this area with the purpose of forming technically qualified engineers with social and human skills suitable to the demands of the current market (RIBEIRO, 2005). Examples of the successful use of active learning methodologies are the experiments of problem-based learning (PBL) in engineering from the universities of Aalborg - Denmark and Newcastle - Australia (RIBEIRO, 2005).

It is noticed that, in Brazil and in the world, higher education courses in the field of health have been pioneers in the introduction of ALM. In the late 1960s, the School of Medicine at McMaster University, in Canada, was inspired by the case study method used in the American universities of Harvard and Case Western Reserve and developed one of the main ALM, the PBL. This initiative has spread over the past decades causing medical and nursing courses to use several other methods that attempt to place the student as an active agent in the process of teaching and learning (BERBEL, 1998 and MITRE et al, 2008).

It is important to contextualize that ALM are practical teaching and learning approaches that seek to place the student as an active agent in his process of knowledge construction. Following the classification of teaching and learning approaches organized by Mizukami (1986) and worked by Santos (2005), there are five approaches to teaching and learning that differ substantially as to the processes of teaching and learning. They are: the traditional, the behaviorist, the humanistic, the cognitive and the socio-cultural approach.

According to Ribeiro (2005) the traditional approach is characterized by keeping the student in a passive posture and the teacher as the sole transmitter of knowledge. Now, in the behavioral approach, there is a view to install in the student the desired behaviors through conditionings and boosters (SANTOS, 2005). The humanistic approach is termed as democratic as the student's interest is taken into consideration for the formation of contents. The cognitive aspect is inspired by the work of Jean Piaget in order to develop student's intelligence through interactionist constructivism. The socio-cultural current, based on the assumptions of Paulo Freire, seeks to develop in the student an attitude of designer and creator of knowledge (SANTOS, 2005).

A parallel between these approaches and the practices of teaching and learning used in engineering education can generate an understanding of the context of the ALM in this scenario. Table 1 shows the characteristics of each approach and how they are reflected in the context of engineering education as explored by the authors Mitre et al, 2008; Santos, 2005; Ribeiro, 2005 and Berbel, 1998. It's possible to see that the humanistic, the cognitive and the socio-cultural approaches are the aspects developing the role of the student as an active agent, and in this context various types of ALM are used.

Table 1: Teaching and learning approaches, the student, the professor and practices used in engineering education

	Traditional	Behaviorist	Humanistic	Cognitive	Socio-cultural
Student's Posture	Passive and assimilator of contents	Efficient and productive when dealing with problems	Active, central, creative, learned to learn	Active to observe, experiment, analyze and argue	Determined by the social, capable of being an agent of change in reality
Professor's Posture	Transmitter of content	Centralizer in the means of teaching selection process	Learning facilitator	Creator of challenging situations	Equal to the student as subjects of the act of knowledge - tutor
Practices of teaching, learning and assessment	Lecture class Written tests	Laboratory roadmaps Evaluation of performance	Group dynamics and problematization Self-evaluation	Problem-based learning Procedural evaluation	Problematization Procedural evaluation

Source: Formulated by the authors from Mizukami, 1986; Mitre et al, 2008; Santos, 2005; Ribeiro, 2005 and Berbel, 1998.

The traditional or conventional approach predominates in engineering education due to various structural, cultural and even individual reasons (Ribeiro, 2005; VILLAS-BOAS et al, 2012). The very sight of segregation and division of labor among knowledge made the higher education of engineering follow a linear, cumulative and rigid training standard present in various curriculum structures. Allied to this, it's noticed that in the context of higher education, the didactic training is deficient and undervalued by many (WEDGE; BRITO and Cicillini, 2006). Thus, it is clear that the traditional teaching methods predominate in a cyclical flow since it is how current professors were trained.

It's noticed that teaching, learning and assessment practices used in engineering education explore little the active role that students can play in the process of teaching and learning. This circumstance indicates that even aspects of the

education of youth and adults, andragogy, are neglected in the practices of these courses. As developed by Knowles, Holton and Swanson (1998), andragogy implies a learning process in which the needs and desires of the learner are the basis of the work. By analyzing the main characteristics of a process seeking andragogical learner autonomy, it is possible to identify that the ALM are in full compliance with these principles.

After an investigation into the ALM used in higher education institutions, nationally and internationally, the practices of class discussion, workshop, problem-based learning, project-based learning, case studies, simulation and conceptual map discussed by Oliveira (2012) were found. In addition to these methodologies, it is worth mentioning the techniques of peer instruction, just in time learning (Araújo and MANZUR, 2013) and team-based learning (MICHAELSEN and SWEET, 2008), in-class exercises, cooperative note-taking pairs, thinking aloud pair problem solving, minute paper (VILLAS-BOAS et al, 2012) and group dynamics (SILVA, 2008) already present in some institutions of engineering education in Brazil.

In an important review of active learning methodologies in process in Brazil, Villa-Boas et al (2012) found 13 strategies in engineering education institutions. The survey was conducted during the Brazilian Congress of Engineering Education in 2011. Among the 500 professors participating in the event, 42 reported using active learning methodologies. The most common were the problem-based learning and project-based learning. The practices of Peer instruction, In-class exercises, Cooperative note-taking pairs, Thinking aloud pair problem solving, Minute Paper, Just-in-Time Teaching were also reported (VILLA-BOAS et al, 2012).

Given the above, it is believed that there is still much to develop, regarding the ALM, in the Brazilian engineering teaching. As stated in the literature, the benefits of these practices are about helping students develop the proactivity and critical insight increasingly necessary to the professional demanded by the market. What these methodologies aim is the development of technical and human skills in an attempt to form not only engineers, but opinion makers and citizens. Another goal that can be achieved by these practices is to enhance the meaning and significance of the content worked by students which would have, in some cases, reflect on the appreciation and consequent permanence of students in the course.

3 Dropout and retention in engineering education

Dropout and retention in higher education have high rates that must be verified and explored. It is important to conduct a study on the reasons that lead to these rates so that actions can be taken in order to identify ways to decrease the values found.

Dropout should be understood as the disconnection of the student from the course in question. This disconnection can happen through transfers, new entrance exams, voluntarily or caused by a process (Adachi, 2009). Now, retention is defined as the student permanence in the institution after the time for completion of the course.

Adachi (2009) presents a formula created by the special committee for dropout study, proposed by MEC, which provides a standardized rate for dropout calculation. This formula considers the full cycle, i.e., including students that should have already completed the course. The dropout % is calculated as follows: $\text{Dropout\%} = [(N_i - N_d - N_r)/N_i] * 100$. N_i is the number of entering students; N_d the number of graduates and N_r the number of retained. It is worth noting that the number of entering students does not only consider students that entered via entrance exam, but also those via transfer, holders of diploma or another valid form within the institution. The number of students retained features those that should be graduated, but that are not, remaining in the institution and the students that are still in course and that are within the time for completion. Graduates are those that have already received the course diploma.

Boero and Silva (2006) describe that the causes of dropout can be listed in three major groups: academic, financial and personal causes. The academic causes include the difficulties presented in the disciplines, whether in relation to the program, professors, teaching methodology or low academic achievement. The Financial causes are related to the family ability to keep the student at the university and in the city. And the personal causes are related to the course choice, school delay, teaching method and frustrations regarding the content presented.

This was also observed by Adachi (2009) when he points out that a study was conducted from 1995 to 1997, by a special committee for dropout study, proposed by MEC (Brazilian Ministry of Education), which was able to identify the main causes of dropout in Brazilian universities. This study grouped the causes into three categories: Student related; course and the institution related; socio-cultural and economic context related.

Furthermore, Boero and Silva (2006) claim that another cause that should be noted is the difference between university courses and high school education levels. This difference ends up making students insecure, causing them to

have frustrations regarding the expectations built.

Furtado and Alves (2012) also believe that, student's secondary school performance ends up compromising the outcome of the first disciplines in university courses, leading to abandonment of the course. Besides that, they believe another reason is that some students seek admission to easier entry programs to try internal transfer to another course. As they cannot always transfer, students end up dropping out of the course and taking another entrance exam.

Furtado and Alves (2012) also show that often the cause of dropout at the beginning of the course is related to difficulties in initial disciplines and professors demands. Now, dropout at the end of the course is related to questions concerning the profession that follows.

Adachi (2009) points out that there are studies showing that one way to avoid disappointment with the course and thus prevent dropout is to encourage academic integration through personal, social and academic commitments. This would eventually develop a bond between the student and the institution.

This idea is justified because one of the causes of dropout is when the individual does not fit in the social environment of the university or when it cannot assess whether the return on investment is advantageous (ADACHI, 2009).

4 Scenario before Conducting the Actions

For the case in study, the Computer Engineering course at Itabira Campus, the first class that entered in Aug/2008 should have completed the course in 2012. Thus, the dropout rate was calculated considering the following values: $N_i = 259$; $N_d = 5$; $N_r = 165$. The rate observed for the course is 34.36%.

The evolution of this value, using the same formula is given as follows: 2009 – 6%; 2010 – 9.09%; 2011 – 20.39% and 2012 – 32.68%. It is observed from the values shown that, in the years 2011 and 2012 there were significant increases in the percentage.

Now regarding the retention, considering the end of 2012 and only the class of 2008 that should be graduated, we have the following values: 50 entering students; 5 graduates; 28 still in course. Therefore, we have a retention value of 62.22%.

According to the three categories presented and the dropout causes listed in section 3, the main causes observed at Unifei Itabira Campus are listed below:

- **Student related:** (1) due to the entry be held, since its first class, exclusively through Sisu, students often come in with a weak high school background; (2) it is often observed that the students do not have the habit of study; (3) as most students are performing their first entry into a university, they often make a precocious profession choice, not knowing exactly what they wish to do; (4) many students report that they cannot adapt to the university life required by the Unifei Itabira Campus; (5) students often enter the course without it being their first choice, which ends up causing demotivation; (6) high failure rate and low frequency in classes; (7) many students do not know the nature of the course or end up discovering new interests, seeking a new entrance exam; (8) students are accepted in another institution closer to home.
- **Institution related:** (9) students do not always know the pedagogical project of the course or its curriculum, which ends up in changes of course due to lack of information; (10) some students complain that some professors are not prepared for University teaching; (11) as the UNIFEI Itabira Campus is a new institution, it lacks special programs, such as PET (Tutorial Education Program) or others that make students feel part of the group; (12) high retention rate in the disciplines makes students not to have sufficient academic performance coefficient to get scholarships for undergraduate research programs, tutoring and other programs; (13) the high number of professors with master's titling makes the professors themselves not eligible to participate in programs of Undergraduate Research with scholarships provided by agencies; (14) as the Unifei Itabira Campus is a new institution, students do not have a referential of the quality of the course; (15) the Science Without Borders program that increases students retention as many of them cannot take courses that could be used in the current course curriculum.
- **Socio-cultural and economic related:** (16) many students do not know the existing labor market; (17) as the campus is new, students believe the main campus has higher quality than the Itabira campus; (18) the city of Itabira has high cost of living; (19) Itabira still does not have adequate infrastructure to student life; (20) many students cannot afford to live in Itabira, which can be verified by the number of ECO (computer engineering) students receiving financial aid, 20 students out of 137 grants, being 14.60% of the total grants.

5 Active Learning Methodologies Used

The actions taken are described below, contextualized with the type of ALM, practices experienced and their educational goals and causes of dropout worked:

- **Name:** Ball-bearing Carts Championship - 3rd Edition. **Type of ALM:** Project-based Learning. **Description:** Students should set up groups of 9 students, build a cart and join a championship. The group should have a mixture of three different engineering and may have senior students in their composition. The entire cost of development should be achieved through sponsorships. The championship is developed as a metaphor of the entrepreneurial process, in which students must set up a team, develop and present the project to investors and get their hands dirty to build a product. Students are instructed to use creativity and innovative elements in the project construction and envisage the experience as their first company. **Practices:** Research and group work; Verbal and oral presentations; Active method. **Educational Goals:** Be able to relate in a group; Make presentations to small groups; Get to know the city and support locations; Learn entrepreneurship; Socialize with students from the university and city residents. **Causes of dropout worked:** 10, 11, and 19.
- **Name:** Computational Projects. **Type of ALM:** Project-based Learning. **Description:** Groups of 5 students with guidance from the course professors. Develop projects related to computing. Tools used: Scratch, Greenfoot, Visual Studio C#, OpenCV, Kinect, Lego, FPGA and Counter-Strike. At the end, a seminar was presented where students could check the project developed by the other students. The division of the groups was performed according to the needs of the project, since some of them had prerequisites. **Practices:** Research and group work; Professor as mentor (tutor); Verbal and oral presentations; Active method; Development of experiments. **Educational Goals:** Being able to relate in a group; Make presentations; Learn concepts of computing in the first semester of the course; Develop experiments in the area; Present the variability in the area of computing (hardware and software). **Causes of dropout worked:** 2, 3, 4, 5, 7, 10, and 11.
- **Name:** Posters Dynamics (THIAGARAJAN, 2008). **Type of ALM:** Write-Pair-Share and discussion in class. **Description:** Students should write what they would like to work on at the end of the course, persuade colleagues to choose their activity and throw the unwanted poster on the floor. At the end, they should make a 30 seconds long advertisement of the chosen activity, trying to convince others to stand with their choice. The choice rounds were finished when there were only 5 posters inside the room, representing the main activities for professionals in the field. **Practices:** Individual and group work; Verbal and oral presentations. **Educational Goals:** Know and describe possible professional activities; develop the ability to convince and persuade; Work in teams. **Causes of dropout worked:** 3, 5, 6, 10, and 16.
- **Name:** Museum Dynamics - Based on the dynamics of Olin College in Dec. 2012. **Type of ALM:** search-group-share and discussion in class. **Description:** Students received a poster in which they should fill with data related to old computer parts. To choose the computer part, the professors made available to the students a series of old computer parts. Students should respond to the following items: team name, team members, their old object (make a drawing); social impacts, building materials, properties and performance; what questions would you like answered about your object; what do you need to know to answer these questions; which disciplines of the grid would provide the knowledge you need to answer these questions. **Practices:** Research and group work; Verbal and oral presentations. **Educational Goals:** Know and describe the existing disciplines in the curriculum; Identify the need to study each discipline; Correlate the knowledge needed to the proposed curriculum; Identify the needs related to each part of the computer. **Causes of dropout worked:** 2, 3, 5, 7, 9, and 10.
- **Name:** Electronics Laboratory Activity. **Type of ALM:** PBL. **Description:** Request the construction of a circuit with logic gates. For the circuit construction, no traditional classes providing a roadmap was given, but the necessary items were made available with a brief description of each item and then they were asked to build the circuit, by "getting their hands dirty". **Practices:** Research and group work; Verbal and oral presentations; Active method. **Educational Goals:** Be able to relate in a group; successfully build the desired circuit; Explain the circuit and how it was assembled; Know and experience the truth tables for each gate; Be in touch with electronics since the beginning of the course. **Causes of dropout worked:** 3, 5, 7, 9, and 10.

- **Name:** Dialogue based lecture classes. **Type of ALM:** Dialogue based classes. **Description:** Traditional Electronics Classes, Computer Architecture and Software Engineering. **Practices:** Verbal and oral presentations. **Educational Goals:** Understand the performance context of a Computer Engineer; Know the curiosities and trends in the area of computing; Understand the interrelation of the various disciplines of software present in the curriculum of the Computer Engineering course at Unifei Itabira; Understand the inner part of the hardware and how it works. **Causes of dropout worked:** 3, 5, 7, 9, and 10.

6 Surveys Results

To evaluate the results achieved with the ALM actions, an online questionnaire was applied with questions on the motivations for entering and quitting the course and on the achievement of the goals of each activity. Of the 45 students registered in the discipline, 37 completed the questionnaire, reaching 82% of the students of the sample.

6.1 Dropout

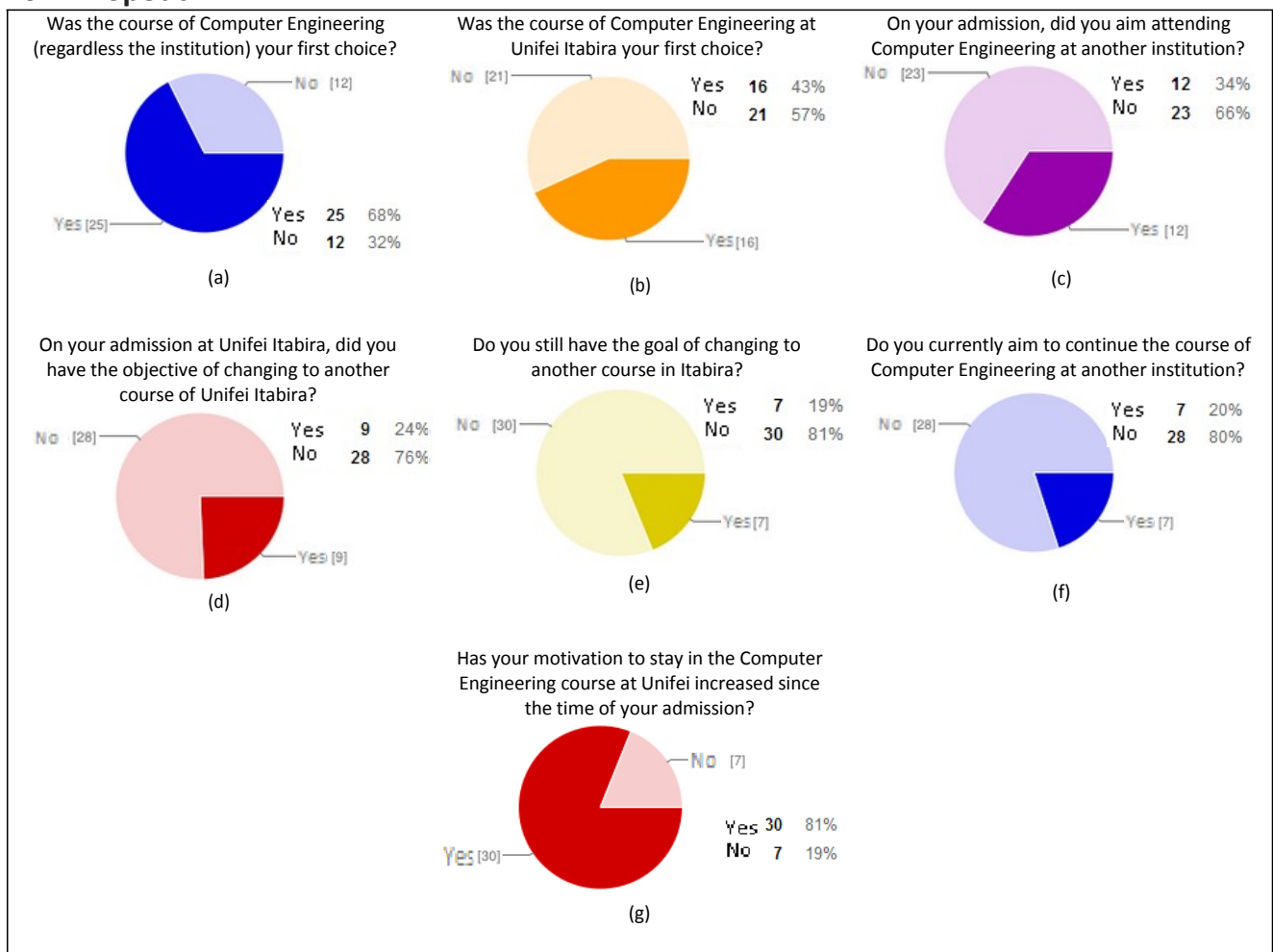


Figure 1 – Survey Results

The graphs in Figure 1 show some results obtained from the survey conducted. We can notice that most of respondents (68%) had as their first option the course of Computer Engineering (Figure 1 - a), however, when asked if they would take it in Itabira, 57% of respondents assumed they did not have the Unifei - Campus Itabira as a first option (Figure 1 - b).

The graph in Figure 1 - c denotes the reality that there are students who enter the course at ECO, but intend to change courses (34%) or institutions.

Comparing the graphs (d) and (e) in Figure 1, we notice an improvement in the dropout rates, for 24% of students reported in Figure 1 - d, that at the time of admission, they would like to change courses. Now in the graph (e) of Figure 1, this value changed to 19%. This indicates that two students who had previously intended to change courses

within the Unifei Itabira Campus have already given up on making the change. This can also be verified by one of the reports of a student who no longer wish to change courses: *"I arrived at the course with the intention of changing, but mostly with the assignments of the First Term and now with ECO10 and BAC06 my interest in the course has increased even further"*.

The graphs (c) and (f) in Figure 1 also show an improvement regarding students who wished to study Computer Engineering at another institution (34%) and those that currently would like to study Computer Engineering at another institution (20%), which represents a gain of five students.

From the data presented, it is believed that there was a reduction in dropout motivation, since after their admission, 5% of students felt motivated to stay in the course and 14% in the institution.

When asked if the motivation to stay in the course increased after admission, 81% answered yes, indicating that even those who have had the course and the institution as a first option felt even more motivated (Figure 1 - g).

Among the reasons for this increased motivation (Table 2), the point of social integration was the strongest (17%), followed by the impact of the subject BACi01 (13%). Other aspects such as proximity and interaction with professors (12%), course design (10%) and the new campus (10%) were also identified as relevant to this motivation.

Table 2: Reasons cited by students for increased motivation to stay in the course and in the institution

Reasons for increased motivation	Rates
I made friends with classmates from Unifei Itabira	17%
The content of the discipline BACi01 and the discussions presented by it	13%
Proximity and interaction with professors	12%
Design of Course in Computer Engineering at Unifei Itabira	10%
The design of the Unifei Itabira Campus	10%
I adapted well to the course of Computer Engineering at Unifei Itabira	8%
The content of other disciplines.	8%
The labor market after completing graduation	7%
I adapted well to the city	7%
Too lazy to try Sisu again	3%
Interaction with the Itabirana community	2%
I do not have a minimum coefficient of performance to try internal / external transfer	2%
Others	1%

Interesting to note that of the top 5 reasons listed, four were worked in the discipline BACi01, integration was worked on activities involving group work, especially in the Ball-bearing Carts Championship, which performs integration with students from various courses and in the Computational Projects. The second biggest reason was the work performed in the discipline itself. The third reason was worked in the Computational Projects. And the fourth reason was worked in the Museum Dynamics.

When asked about the motivation to change courses and institution, it is clear that the strongest reason for dropout is the fact that the course (Table 3) was not their first choice (36%) followed by the perceived difficulty of the course. With regard to the institution (Table 4), the proximity of the family seems to be the strongest factor for dropout desire (36%) followed by the perceived high cost of living in the city of Itabira (27%).

Table 3: Reasons cited by students for changing courses

Reasons for changing courses	Rates
Affinity with the target course	36%
Difficulty of the Computer Engineering course	18%
It was not my first choice course	14%
The labor market after completing graduation	14%
Lack of affinity with the Computer Engineering course	9%
I had/ have no idea of what I would like to attend	9%
Easiness of the target course	0%
Other	0%

The factors presented are complicated to be worked in a single discipline. The fact that the discipline is not their first choice highlights a potential problem generated by Sisu that enables students to end up trying to courses that they previously would not do if there was no facility to exchange places and check if they were approved that the project allows. It is believed that this factor should be studied, not only in the ECO at Unifei Itabira, but in several educational

institutions that use the Sisú for entrance.

The difficulty of the course is an issue that should be worked on within the course or even in the institutional scope, enabling individual monitoring of students who have more difficulty, not allowing these difficulties to be a determining factor for dropout.

Table 4: Reasons cited by students for changing institutions

Reasons for changing institutions	Rates
The institution is closer to my house	36%
High cost of living in the city of Itabira	27%
I believe that the target institution is better	14%
I did not adapt to the city of Itabira	14%
Difficulty integrating with the community of Itabira	5%
Other	5%

Now, regarding dropouts due to the proximity of the family, it is believed that this is a cause extremely difficult to be minimized. It is also believed that, this factor was aggravated by Sisú, which facilitates the insertion of students from any part of Brazil in a much easier way. The high cost of living in the city of Itabira however is a factor that can be improved institutionally with the increase in the number of assistance grants.

6.2 Results of the ALM activities and Discussions

Regarding the fulfillment of objectives of the ALM used in the discipline Baci01, the data in Table 5 indicate that it was possible to present the skills and abilities of a Computer Engineer during the discipline. There was the increase in knowledge of 46 percentage points among the participants. The objective of presenting the differences between the courses related to ECO was also fulfilled. These items were worked, mainly, by the posters dynamics and the museum dynamics activities, demonstrated by the existing educational goals in these activities: Know and describe possible professional activities; Know and describe the existing disciplines in the curriculum; Correlate the knowledge needed to the proposed curriculum.

Table 5: Percentage of students who increased knowledge regarding the carrier and the course of ECO

Percentage of students who increased knowledge about ECO	Rates
% of students that, when enrolling in the course knew the skills and abilities of a Computer Engineer	46%
% of students that, after taking the Baci01 discipline, knew the skills and abilities of a Computer Engineer	95%
% of students that, after taking the Baci01 discipline, knew clearly the differences between the courses of Computer Engineering, Computer Science and Information System	81%

To survey the fulfillment of the objectives of each ALM applied in the discipline Baci01, a scale from 1 to 5 was proposed to the students, where 1 could express “Do not agree” and 5 for “Strongly agree” as to their perception of fulfillment of the objectives of each activity. To summarize the results, it was considered the sum of the percentage of marks to grades 4 and 5. Thus; the following compliance rates for the objectives of the actions were found.

Below are the tables with the compliance rates for each goal, and in the first line is the overall index of the action:

Table 6: Compliance rates for the objectives of the 3rd Ball-bearing Carts Championship (project based learning)

3rd Ball-bearing Carts Championship	Rates
Be able to relate in a group;	71%
Make presentations to small groups;	58%
Get to know the city and support locations;	52%
Learn entrepreneurship;	74%
Socialize with students from the university and city residents.	58%
Increase my motivation to continue the course in Computer Engineering at Unifei Itabira	23%

It's noticed, from Table 6, that this ALM was effective in working interrelationship skills and learning entrepreneurship, not getting, however, impact on the direct goal of motivating students for the ECO course. This activity aimed to work out the causes of dropout: professors not prepared for teaching; lack of special programs; infrastructure of Itabira city.

The cause “Lack of special programs” was attacked, since the event as a whole can be considered a special project

within the institution, since each issue involves all students entering the institution, making a total of 450 students.

As for the city's infrastructure, the goal "Get to know the city and support locations" (52%) is the objective that seeks to remedy this cause of dropout, since by getting to know the city the students eventually identify the locations in which their main needs are found.

Regarding the cause "professors not prepared for teaching", we understand that it is present in all activities, since many professors of the course were involved in the project and the activities presented here had to be studied in order to meet the proposed objectives and also, solve or minimize the causes of dropout highlighted.

Table 7: Compliance rates for the objectives of the Computational Projects (project based learning)

Computational Projects.	Rates
Be able to relate in a group	80%
Make presentations	69%
Learn concepts of computing in the first semester of the course	94%
Develop experiments in the area	88%
Present the variability in the area of computing (hardware and software).	83%
Increase my motivation to continue the course in Computer Engineering at Unifei Itabira	72%

This ALM was quite effective with respect to its objectives, especially for attacking one of the main reasons for dropout which is the lack of vocational content in the early stages of the course (Table 7).

The causes of dropout highlighted were: students have no study habit; students do not know exactly what they want to do; students cannot adapt to university life; the course is not the student's first choice; students do not know the course; professors not prepared for teaching and lack of special programs.

For the causes "students have no study habits" and "students cannot adapt to the course," the computational projects are guided by professors, that get to know closely the students and help them learn how to study, improving their performance and, consequently, the adaptation to the course.

The objectives "Learn computing concepts in the first semester of the course," "Develop experiments in the area" and "Present the variability of the area of computing (hardware and software)" tried to remedy the causes "students do not know exactly what they want to do" and "students do not know the course."

The reason "lack of special programs" is highlighted by the activity itself, which can be understood as a special project. Now, the reason "course is not the first choice", it is believed that the student has some affinity with the course since he chose it, even not being his first choice. Thus, with the completion of the project, the student may feel motivated to stay in the course. However, this action can also make the student realize that he does not have the profile, or indeed understand that he does not want to go on with the course. This ALM had significant impact for the knowledge of professional skills and for developing communication skills (Table 8).

Table 8: Compliance rates for achieving the goals of the Posters Dynamics (write-pair-share and discussion in class)

Posters Dynamics	Rates
Know and describe possible professional activities	74%
Develop the ability to convince and persuade	74%
Work in teams	69%
Increase my motivation to continue the course in Computer Engineering at Unifei Itabira	55%

The causes of dropout worked in this activity were: students do not know exactly what they want to do; the course is not student's first choice; high failure rate and low frequency; professors not prepared for teaching; students do not know the labor market.

Except for the cause "professors not prepared for teaching", all others are attacked by the goal "discover and describe possible professional activities".

As it happened in the previous activity, the course not being the student's first choice and the students not knowing exactly what they want to do, the objective can help by bringing greater knowledge of the area, which contributes to the definition of the student's needs.

Now, the high rates of failure and low frequency, are attacked, as students know better the labor market, they also know the course better, and can identify the need for knowledge in each area. In addition, students can be motivated to stay in the course, and also stimulated in their attendance in the disciplines.

The cause "students do not know the labor market" is the most adherent to this activity, since its main purpose was exactly to show the labor market that Computer Engineers have at their disposal.

Table 9: Compliance rates for achieving the goals of the Museum Dynamics (search-pair-share and discussion in class)

Museum Dynamics	Rates
Know and describe the existing disciplines in the curriculum of the course	83%
Identify the need to study each discipline;	89%
Correlate the knowledge needed among the disciplines of the course curricular structure	82%
Identify the knowledge needed to build computing devices	83%
Increase my motivation to continue the course in Computer Engineering at Unifei Itabira	61%

This ALM obtained strong success by presenting students with the knowledge to be acquired during the course. Although moderate, it could also motivate students for the course (Table 9).

The causes of dropout highlighted were: students have no study habit; students do not know exactly what they want to do; the course is not the student's first choice; students do not know the course; students are unaware of the pedagogical project of the course; professors not prepared for teaching.

The actions "students do not know the course" and "students are unaware of the pedagogical project of the course" are attacked directly by the activity, since it works in the knowledge of the curricular structure of the course.

For the causes "students do not know what they want to do" and "the course is not the first choice" just as in the previous activity, knowing the course, can make students decide not to drop out.

For the cause "students have no study habits", the objective "Identify the need for studying each discipline" will contribute to this activity, as students will need to seek knowledge to perform the activity, developing their study habit.

Table 10: Compliance rates for the Electronics Laboratory (problem based learning) goals

Electronics Laboratory	Rates
Be in touch with the electronics since the beginning of the course	88%
Increase my motivation to continue the course in Computer Engineering at Unifei Itabira	73%

This ALM was effective as to the motivation and regarding the anticipation of vocational content to the beginning of the course (Table 10). The causes of dropout worked are: students do not know exactly what they want to do; the course is not the student's first choice; students do not know the course; students are unaware of the pedagogical project of the course; professors not prepared for teaching.

All causes, except for "professors not prepared for teaching", are treated by this activity, because bringing forward the content of the curricular structure motivates students and make them understand which activities are important for the proposed training. It also enables greater knowledge of the course, making those who could quit the course no longer do it.

Table 11: Compliance rates for the goals of Traditional classes of Electronics, Computer Architecture and Software Engineering (dialogue based lecture class)

Traditional Classes of Electronics, Computer Architecture and Software Engineering	
Understand the performance context of a Computer Engineer	89%
Know the curiosities and trends in the area of computing	86%
Understand the interrelation of the various disciplines of software present in the curriculum of the Computer Engineering course at Unifei Itabira	70%
Understand the internal part of the hardware and how it works	78%
Increase my motivation to continue the course in Computer Engineering at Unifei Itabira	69%

This ALM was effective as to the motivation and regarding the anticipation of vocational content to the beginning of the course (Table 11). The causes of dropout worked are: students do not know exactly what they want to do; the course is not the first choice of the student; students do not know the course; students are unaware of the pedagogical project of the course; professors not prepared for teaching.

Similarly in the previous activity, this allows students to have knowledge regarding the course, enabling the reduction of dropout.

Regarding the overall fulfillment of objectives, the actions Computational Projects, Electronics Laboratory and Museum

Dynamics were the most successful with overall percentages above 80%.

Since the objective of motivating students to continue in the course of Computer Engineering at Unifei Itabira was the most important, it is worth examining the actions that contributed most to this. In Table 12 are the results indicating that the activities of technical nature were the ones that most fulfilled this role.

Table 12: Activities classified as to the impact on the motivation to continue in the course and at Unifei Itabira

Activities classified as to the impact on the motivation	Rates
Electronics Laboratory	73%
Computational Projects	72%
Traditional Classes of Electronics, Computer Architecture and Software Engineering	69%
Museum Dynamics	61%
Posters Dynamics	55%
3rd Ball-bearing Carts Championship	23%

7 Final Remarks

After reporting this experiment, we can conclude that some causes of dropout were not worked during the Baci01 discipline activities for being out of the reach of a single discipline. However, it is worth reflecting on some actions that have been executed within the direction and coordination of the course. With regard to the first cause (previous educational training deficit), it was established at Itabira Campus the discipline Calculus Zero which aims to level student's knowledge in relation to this area. With this action, it is possible to partially resolve the deficiency of training of the newcomer. Cause 13 (access restriction to scientific initiation programs due to the fact that most professors do not have a doctorate degree) has been countered with a policy of teacher training that is being formulated, which intends to regulate and facilitate the process of teacher training for those who have not yet doctorate.

We believe that cause 20 (students financial hardship) can be minimized by strengthening student assistance, an action that also competes to the direction of the institution. In this context are causes 17 (perception that the main campus based in Itajubá is better than the Itabira campus) and 14 (the lack of a quality referential of the course, since the institution is new) it is necessary to develop a policy of upgrading local results, through the disclosure of Itabira campus quality indicators that could strike these causes.

We understand that cause 12 (access restriction to scientific initiation due to low coefficient of performance) can be minimized over time, reflection of the set of actions that are being performed. This is due to the fact that this issue involves not only an improvement of the institution and teaching practices used by professors, but also by changing student's attitudes towards their learning process.

Some dropout causes were considered outside the institution scope of action as a whole, they are: 8 (the need to study close to the family), 15 (retention caused by the Science without Borders Program) and 18 (high cost of living in the city of Itabira).

Based on the data collected, it was possible to identify that dropout rates can be minimized through the use of ALMs. The Data indicate that the activities were effective, to a greater or lesser extent, in increasing student motivation and reducing dropout intention. However, we concluded that the actual dropout rate will not be reduced immediately. In the short term, it will also not be measured improvement in the quality of student education, as recommended by MEC.

On the other hand, it is believed that the continuity and improvement of the activities reported in this paper may contribute to students, that have or not the ECO course as a first option, understand the course proposal. This will motivate the permanence of those who actually identify themselves with the course and allow on the other hand, that some of them who are certain that their course choice was not correct.

It is important to note the impact that this experiment generated to the formation of the faculty involved. It allowed the authors, the exchange of experiences and the consolidation of teaching practices revealing the truth advocated by Paulo Freire that "One who teaches learn as they teach and one who learns teach as they learn " (Freire, 1997). This experiment was not limited to the three professors directly involved, but it also impacted six other professors that acted as tutors in the Computational Projects activity.

It is worth mentioning that the experiments reported have produced effects in other areas of the course directly linked to the causes of dropout. New projects are being designed to be implemented in the next year, besides that, changes in the curriculum will be proposed in order to anticipate the vocational content.

As future work, we believe it is necessary to conduct a thorough study on the entry way (Sisu), which allows the enrolment of students that wouldn't be able to enter before.

Finally, despite of actions on a single discipline having scope limitation, we realize that their reflexes and especially the analysis of their results can provide important actions. Initiatives in different areas that, together, can contribute to a significant reduction of dropout causes in engineering courses.

Acknowledgement

We thank all the professors who actively participated in the computing projects: Alessandro Campos, Claudia Izeki; Evandro Cotrim; Juliano Monte-Mor; Natália Cosse; Walter Nagai; Wandré Veloso; Fernanda Silva. We also thank all the students who agreed to answer the questionnaire, enabling the completion of the qualitative analysis of this research.

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Active Learning to prevent Evasion in Engineering Courses?

Liane Ludwig Loder^{*}, Osvaldo Shiguero Nakao⁺, Alberto Bastos do Canto Filho^{**}

^{*}Electrical Engineering Dep, Federal University of Rio Grande do Sul, Porto Alegre, Brazil

⁺ Polytechnic School of University of São Paulo, Brazil

^{**} Electrical Engineering Dep, Federal University of Rio Grande do Sul, Porto Alegre, Brazil

Email: lianeludwig@ufrgs.br, osvaldo.nakao@poli.usp.br, alberto.canto@ufrgs.br

Abstract

The training of innovative, independent and enterprising engineers is the desired goal of engineering educators, which is further promoted by demands from the labor market. It is increasingly understood among such professionals that these essential quality parameters, underlying the educational objectives of contemporary engineering courses, can only be achieved through appropriate pedagogical interventions. In this regard, based on the fundamental aspect of encouraging students to play a larger role, pedagogical interventions rooted in the principles of Active Learning are appropriate strategies for achieving training, on a large scale, without loss of quality.

This article will discuss the causes of the high prolongation and dropout rates of students in engineering disciplines, as well as the blatant lack of interest on the part of high school students to study engineering. On the basis of this discussion, possible solutions and suggestions will be put forth to change the current status quo to achieve the goal of training a larger number of engineers with quality education.

Effective pedagogical interventions, which are anchored in learning, seem to be a potentially successful alternative in the quest to lower dropout and prolongation rates, train an increasing number of qualified engineers with qualified education and implement the recommendations of the Ministry of Education (MEC) related to reducing the number of dropout students.

Keywords – Active Learning, Dropouts in Engineering Courses, Engineering Education.

Session Type: Debate Session

1. INTRODUCTION

Various studies show that in order to achieve sustainable development that promotes social inclusion it is important to have a massive number of engineers in the production market. According to information from CONFEA (Federal Council of Engineering, Architecture and Agronomy), there are approximately 600,000 registered active engineers. This is the equivalent of six professionals per 1,000 workers, far from the rates of developed countries, such as Japan and the United States, where the average is 25 per 1,000 (TELLES, 2009). Furthermore, according to the

market there is currently a shortage of 20,000 engineers in relation to market needs (SILVA, 2013). Nevertheless, the percentage of students in engineering courses is insufficient to revert this situation in the short term, as shown by the most recent Higher Education Census, with data from 2010, where only 3.9% of enrollments in university courses are in engineering (INEP/Censup, 2011) and only 5% of total graduates are from engineering (CNI, 2013).

The training of innovative, independent and enterprising engineers is the desired goal of engineering educators, and it is driven by demands from the labor market. It is increasingly understood among such professionals that these essential quality parameters, underlying the educational objectives of contemporary engineering courses, can only be achieved through appropriate pedagogical interventions. In this regard, based on the fundamental aspect of promoting students to play a larger role, pedagogical interventions rooted in the principles of Active Learning are appropriate strategies for improving the university graduate/freshman ratio without loss of quality.

For the purposes of this discussion, successful teaching strategies are those which, in accordance with certain quality standards, result in students completing their courses within the prescribed time frame of ten semesters, as established by Brazilian law.

This concept of "academic success" based on students completing their studies program is supported by the finding that in some Brazilian disciplines, offered in renowned, longstanding universities, only half of the entrants finish their degrees (LODER, 2009). Therefore, completing university, both for the student and society, is a great feat.

The prolongation of studies, as evidenced by the increased length of time students are taking to get through the course, and dropouts, responsible for the small pool of engineers in the labor market, cause problems in students' lives and in the management of these courses. Therefore, actions taken to minimize these rates, while maintaining quality levels, are in the great interest of academic communities in general.

The drop in the number of engineering graduates and negative consequences for the country's development incites educational institutions and the government to pay attention to these rates and monitor their development while, at the same time, seeking solutions to minimize them. In this context, professors and their teaching methods, as well as the access of students to universities and their remaining in them play a critical role.

Simply increasing the number of places in engineering courses, to overcome these difficulties and quickly boost the number of engineers in the market, is an alternative that has certain limitations. This is due to the fact that the time between the creation of a place for a first year engineering student and the entry of that professional in labor market is approximately six and a half years (LODER, 2009) and also because the creation of new institutions and courses requires significant investments. In light of the difficulties inherent in creating new places, it is then a beneficial alternative to combat dropouts and prolonged duration of studies, in view of its low costs and the possibility of increasing the number of engineering graduates in a shorter period of time. Given the lack of interest in engineering courses, greater interaction between universities and high schools is increasingly urgent.

When this topic is discussed in the Debates Session at ALE 2014, hopefully it will be possible to envision new alternatives that will enable more engineers to be trained in the future, without having a high number of dropouts (on average, in Brazil, less than 50% of freshmen complete the course), as has been observed.

2. PARAMETERS, INDICATORS AND CAUSES OF DROPOUTS AND PROLONGED STUDIES

2.1 Dropouts and Prolonged Studies

Dropouts, understood as the percentage of students who leave engineering courses, is a phenomenon that occurs in all courses, and in Brazil, is higher in private universities. Studies also reveal that dropping out occurs much more during the first two years of the course, a fact generally associated with lack of prior knowledge on the part of students.

For purposes of calculating the dropout rate, it may take into account students who having failed to obtain their degree did not enroll for the following year or semester, as well as students who do not finish the course after a certain length of time. Additional factors to be considered are students on academic exchange programs, with courses

that are expiring or transferred (from the course and towards the course). Some institutions consider as dropouts those who were approved in the selection process and did not enroll.

Prolongation is understood as the stretching of the number of years to complete the degree, beyond the recommended period of five years, which may be one of the causes for students dropping out. Continually having to retake courses, due to failing them, leads to extending the length of time in university and slows down the curricular flow of the student.

For calculating the prolongation rate, the main issue is defining at what point the student should be in the curriculum, considering the length of time of they have been in the course. For both yearly sequential courses as well as electives, the position of the student may be characterized by missing courses or failed courses, and this position is compared with length of time in the overall course. A certain flexibility should be taken into account due to failure rates in engineering courses.

2.2 Dropout and Prolongation Rates

Data from the Anísio Teixeira National Institute for Studies and Research Teixeira (INEP), from 2000 to 2005, indicate that the average dropout rate in Brazil is 22%, taking into account all the courses, with 12% in public institutions and 26% in private ones. The dropout rate in production and construction engineering was on average 21%, very close to the national average.

Silva Filho et al (2007) comment that dropout rates, worldwide, during the first year of undergraduate courses, are two to three times higher than in the following years. Studies conducted by OLIVEIRA (2011) confirm these results. According to his data, the dropout rate (percentage of new students in engineering course who leave the course before finishing it) is, on average, higher than 50%. In public universities, the dropout rate is around 40% and in private ones it is approximately 60%.

Studies conducted at the Federal Technological University of Paraná - UTFPR (DALLABONA & SCHIEFLER in OLIVEIRA et al, 2012) indicate that only 31% of students are able to complete the entire course within 10 semesters, which is the expected time in the corresponding pedagogical projects. This time frame extends up to 19 semesters, linked to the regulatory deadline resulting in the student's dismissal. These authors also note that approximately one third of the students are able to complete the course within the allotted time. Another third require an additional year and another third need a longer time. The average time for completing the course is 6.2 years, ranging from 5.9 to 6.4 years, depending on the course. Note that this average takes into account the entire history of the courses, from the beginning. Electronic and electrical engineering started their academic activities jointly in 1978, while mechanics began in 1992 and civil in 1996.

Also in terms of prolongation rates, these studies indicate that only 43% of the engineering students at UTFPR are in the semester corresponding to their normal course schedule or ahead of it. The distribution between the courses ranges from 37% in electronic engineering and 54% in control and automation engineering. It must be taken into consideration that control and automation engineering and computer engineering are disciplines in the process of being implemented, which reduces the prolongation rates. The differences between the disciplines merit an explanatory study, and could examine the hypothesis that there is a strong influence of the selection process, i.e., the applicants/places ratio and the average score of the freshmen.

2.3 Causes for dropouts out and prolonged studies, as revealed by different studies

Many authors claim that successive failures in individual courses are one of the leading causes for students prolonging their studies and, consequently, dropping out. The most commonly cited cause for this phenomenon of failure is the increased number of freshmen entering the university with gaps in their pre-university education in exact sciences.

The school environment of the university which is totally new to freshmen is another cause of academic failure presented by SOARES (2006).

In addition, the choice of a profession without having the necessary knowledge about it, likewise appears to contribute toward high dropout rates in the initial phase of engineering courses.

Another possible cause cited in the study by SOARES (2006) refers to the distant relationship with professors, especially in the early stage of the courses where class sizes are large, exceeding 50 students. There are also indications that foreign professors who cannot express themselves well in Portuguese hinder students from learning. Another factor put forth by the author is the dedication of professors to their research projects when related to their teaching activities, which end up competing with each other, to the detriment of teaching, most of the time. Some other causes noted by SOARES (2006) include: the need for students to enter the job market early and the subsequent difficulty in juggling work and studies, in addition to the "study for the test" mentality that often takes root in the school context.

There are also situations that mask the dropout and prolongation rates. A typical example is the case of students who do entrance exams for several universities, are approved in some and enroll in more than one, especially public ones. However, they are only studying in one university and fail to cancel their enrollment in the others, resulting in what appears to be dropping out of those ones. Another common situation is falling behind voluntarily. Students, for the sake of convenience, may choose to complete the entire course in more than ten semesters and are, thus, assigned the status of being behind semester-wise, despite having no failed courses on their academic transcripts.

2.4 Suggestions for minimizing dropout and prolongation rates

Given the scenario under study, there are different options that could mitigate dropout and prolongation rates:

- Welcome the differences of each student, since academic success depends on adapting to higher education;
- Provide scholarships to ensure the livelihood of students and the funding their studies;
- Promote activities in the courses that foster greater interaction between the university and companies;
- Offer courses that focus on the learning process and that promote skills and competences;
- Implement academic tutoring programs, so that professors are able to monitor and guide the educational path of students;
- Set up a group or committee for academic guidance and monitoring that will organize tutoring activities and continuously engage in monitoring and discussions on issues related to student academic performance, including dropouts and prolongation;
- Identify, in a structured way, the most critical courses in each discipline and monitoring those enrolled in classes in a different manner, in an effort to find and implement improvement measures;
- Expand the role of students who act as monitors;
- Lower the number of students per class;
- Authorize extra-curricular internships only in more advanced stages of the overall course to prevent students from becoming a source of cheap "labor";
- Set up an Evaluation Board for each stage of the engineering course in order to better assess the academic situation of each student and take more effective corrective actions;
- Foster a study culture, which is systematic and continuous, as opposed to the "last minute" study habits on the eve of exams;
- Make extensive use of academic exchanges as a way to "broaden the educational horizons" of students;
- Use management tools that enable preventive actions to be taken to avoid dropouts;
- Provide professors with pedagogical training.

2.5 Suggestions for increasing the number of engineering graduates

It is necessary to increase the number of engineering graduates, in order to achieve the goals set by the National Confederation of Industries (CNI, 2013), wherein, by 2022, 15% of all university students would be studying engineering, which means tripling the current rate.

With this target in mind, deemed sufficient by the market, activities also need to be promoted that will increase the number of freshmen, over and beyond developing managerial and teaching/pedagogical strategies to minimize dropout and prolongation rates of students who start studying engineering.

From this perspective, universities need to take action to spark the interest of elementary and high school students in engineering careers. Such actions entail highlighting the role of engineers in society and the impact of their activities on the country's development, as well as initiatives to integrate these students, such as:

- Implement "Open Door" programs, in which the University opens up to the community by promoting regular guided tours of its campuses;
- Include elementary and high school in activities such as the Scientific Research Symposium;
- Encourage high school students to participate in competitions such as "Robot Challenge" and similar competitions in different engineering disciplines;
- Conduct exchange programs with schools to support them in carrying out Science Fairs and related activities, such as the participation of high school students in Mathematics and Science Olympic Games.

3. FINAL CONSIDERATIONS

Dropping out and prolonging the completion of degrees by students is caused by a variety of factors whose relevance depends on the context in which dropping or prolongation occurs. It would seem that in private universities the high financial investment required on the part of students and their families is a leading factor. The discussion on this topic has brought to light other possible causes, such as the increased number of freshmen entering university with gaps in their pre-university education in exact sciences; the university milieu representing a totally new environment for freshmen; premature career choices; difficulties in creating close professor/student relationships; and the need to juggle work and studies on the part of students.

Some possible solutions to reduce dropout and prolongation rates include (in relation to students dropping out): provide ongoing scholarships; other financial support in the form of meal vouchers, health care programs and student housing, all based on good school performance as a counter-requirement; provide courses that interact more with companies; use teaching strategies focused on the learning process and the development of skills and competencies; closer monitoring of students' academic paths and, lastly, better pedagogical training for Engineering professors.

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Using Active Learning by teaching at the Classroom with a Remote Lab

Darinka Ramírez* & Manuel Macías*

*Departamento de Ingeniería Química y de Ingeniería Eléctrica, Tecnológico de Monterrey, Campus Monterrey, México

Email: darinka@itesm.mx, mmacias@itesm.mx

Abstract

The aim of this paper is to describe the experience and the value added of teaching an engineering course of 3rd semester by having access to a remote laboratory experiment from the classroom at the same time. With the support of the online experiment, the instructor is able to go through the mathematical modeling of the situation while observing in real time what is going on in the process. This allows students to do active learning while conducting real experiments and calculations from their desks at the classroom site. The results of this study showed that the students learning style is visual (86.2 %); they like to learn actively (71.3%) and they preferred to learn using technology (87.2%). This idea could engage more students from early stages of high school and engineering education.

Keywords: active learning; remote lab; engineering students.

1 Introduction

Among all the issues that learning has, Stice (1987) writes that one of the problems is that students retain 10 percent of what they read, 26 percent of what they hear, 30 percent of what they see, 50 percent of what they see and hear, 70 percent of what they say, and 90 percent of what they say and do. In that sense, they get easily distracted. This is one of the reasons why we can only engage a small percentage of the students during an average class. Another problem is that instructors, when teaching mathematics and engineering only by writing and lecturing on the board, most students fail to see the meaning of the equations: they just memorize the method and learn it in a sequential way, without a full understanding of the whole concept and its real world applications. This is one of the reasons why Tecnológico de Monterrey (<http://mx.noticias.yahoo.com/presentan-modelo-educativo-tec-21-000847066.html>) has launched the Tec 21 Educational Model Initiative.

Also, this problem seems to be worse at high school and the early stages of engineering education, mainly at the basic courses of science: Chemistry, Physics and Mathematics causing a large number of students to drop out. Therefore, the idea proposed in this paper, particularly on the Engineering field, is the incorporation of laboratories in the curriculum as a critical issue. However, there are limitations regarding the schedule and space availability to carry out experiment activities. The incorporation of remote laboratories during classes could help this situation. Remote experiment equipment is a completely automated device which can be operated from far.

Thanks to the current advantages of audio and video streaming via internet, this remote laboratory allows the user to have a real time image of what the experiment equipment is doing, as well as information regarding the condition of the operation and response variables, also in real time. Since it is completely automated, the remote equipment allows remote operation at any time of the day, which gives courses a degree of flexibility to schedule their experiment activities.

The expected impact of the remote laboratory on traditionally theoretical courses is that students and teachers can show, via experiments, the principles and theories taught in class, achieving a better understanding of these concepts. Furthermore, the use of experiment activities as part of the course activities motivates and engages the students, improving the experience during the teaching-learning process.

The present proposal uses the remote laboratory as an educational innovation by interacting with it at the same time the teaching-learning process takes place in the classroom. In this way, the teacher can connect theory with real practice (by having remote access to the laboratory using cameras) in their own classroom. The laboratory isn't used after learning the theory, nor before, but at the same time. This also means ensuring that graduates are able to apply theoretical knowledge to industrial problems, as well as possessing theoretical comprehension (Ramírez & Macías, 2013), creativity and innovation, teamwork, technical amplitude and business skills. This is why educational programs must be up to date with the ever changing needs of the industry, with an even greater interaction between services and the industry itself (Graham, 2012).

2 Development

2.1 Design of the remote laboratory

The course for which this idea was developed was Material Balances (IQ-10001), which is an Engineering class from the Chemical Engineering department taught to 3rd semester students of the Chemical Engineering, Industrial Engineering, Food Engineering, Sustainable Development Engineering and Biotechnology Engineering careers (on average, 300 students take this course each semester). The topic for which the laboratory is mainly used is *Transitory State*, wherein differential equations are used to solve problems. Given how diverse the students' profiles are, the remote laboratory can be of great help to understand the topic.

The teaching-learning process of Material Balances had been, for the longest time, a traditional affair of a Chemical Engineering class using chalk and chalkboard. This process has undergone recent modifications, with teachers introducing examples using computers and incorporating green engineering problems (Slater & Hesketh, 2004), as well as using active learning techniques (Gooding, 2005; Bullard & Felder, 2007). However, none of these new ways of teaching the class had implemented the visualization of a system with intakes and outtakes at the tank. The proposed process can be operated in the classroom simultaneously while the teacher explains the basic concepts of material balances in real time.

2.2 Building the remote laboratory

The remote laboratory consists of a tank interconnected by pipes in a closed circuit. The system is fully automated and connected to a network card, which allows for remote manipulation (Figure 1).



Figure 1: Remote laboratory.

The remote laboratory's access interface is used as a work tool so the teacher and students can interact with the process and verify its operation in real time. The access interface is composed of two parts: the Graphic User Interface and the Audio-Video Interface. The Graphic User Interface functions as "the hands" of the user in the laboratory, and it is used to control and modify the process being carried out (Figure 2).

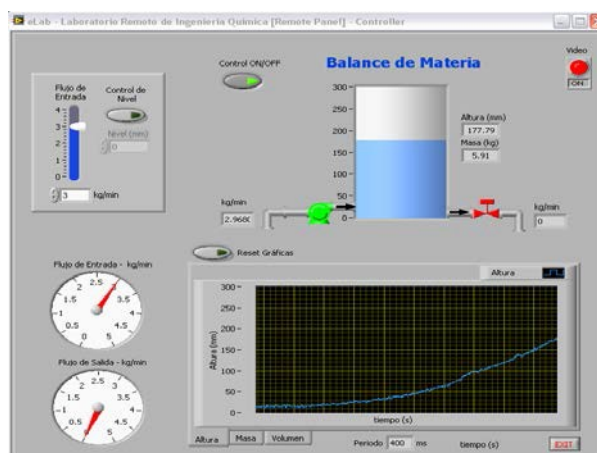


Figure 2: Graphic User Interface.

The Audio-Video Interface (Figure 3) is the “eyes and ears” of the user in the laboratory, and it is used to observe the actual real process and check its behavior.

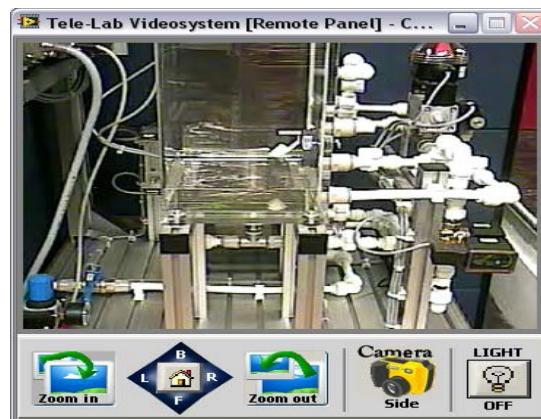


Figure 3: Audio-Video Interface.

2.3 Use of the remote laboratory in the classroom

The teacher first performs a virtual tour of the laboratory via a live feed projected onto a screen in the classroom using the Audio-Video Interface, while he or she explains the equipment's components. This is how students observe and familiarize themselves with the details of the system. The teacher can use the camera to zoom in so students can observe the tank and pipes, the intake and outtake sections of the tank, the flow, the transport, the control valves and the whole water transport circuit of the process.

Afterwards, students calculate the tank's dimensions in order to obtain its total volume, so they can determine the tank's maximum capacity of water. Then, the students use the Graphic User Interface to observe that only the intake flow can be controlled (with a maximum capacity of 4kg/min). They also find out that there is no outtake flow control for the tanks, as it occurs assisted by gravity.

The students then perform different tests with the equipment to analyze its operation, waiting times and behaviors observed on the graph (the Graphic User Interface, which could be used to measure the level, mass or volume against time).

Further examples are conducted this way, experimenting in the classroom until there's a full understanding of the concepts and application of the topic. The laboratory is also used to explain other topics like: flow diagrams, industrial equipment, stationary state and so on.

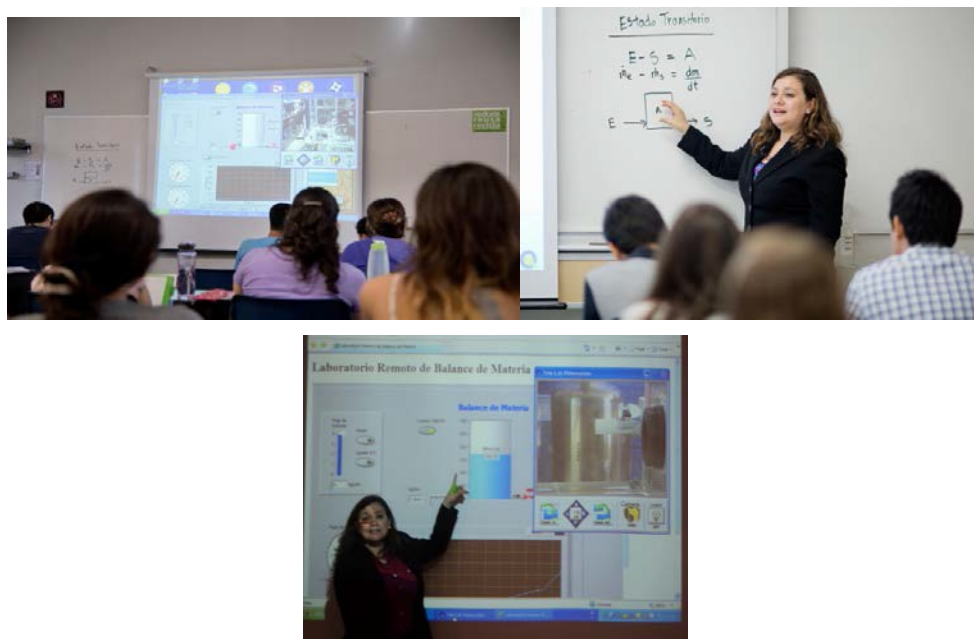


Figure 4: Using the remote laboratory in the classroom.

3 Evaluation and Results

Two specific actions were taken in order to evaluate the impact the remote laboratory could have on the students using this teaching-learning model: I) Evaluation of learning styles and II) surveying the students regarding their perception of their own learning.

3.1 Analysis of learning styles

The research approach used to evaluate learning styles was quantitative based, using a closed-ended questionnaire. The evaluation of the learning styles was conducted according to the proposal presented by Felder (1988), which focuses its study mainly on the engineering area (Felder, 1988). This proposal posits that a student's learning style can be determined by the answers of five questions:

- 1) What type of information does the student preferentially perceive: *sensory* (external), like sights, sounds, physical sensations, or *intuitive* (internal), like possibilities, insights and hunches?
- 2) Through which sensory channel is external information most effectively perceived: *visual*, like pictures, diagrams, graphs and presentations, or *verbal*, like words and other audible sounds? (Other sensory channels, like touch, taste and smell, are relatively unimportant in the majority of educational environments and are not considered).
- 3) Which type of organization of information is the student more comfortable with: *inductive*, (facts and observations are given and the underlying principles are inferred) or *deductive* (the principles are given, but the consequences and applications are deduced)?
- 4) In which way does the student prefer to process information: *actively* (through participation in the physical activity o debate), or *reflectively* (through introspection)?
- 5) How do students' progress through their understanding: *sequentially* (in continuous stages) or *globally* (in giant leaps, holistically)?

The students answered a standardized questionnaire composed of 44 questions and applied via internet. Results were determined automatically and feedback was practically immediate (it only takes a few seconds for the learning style to appear on screen). That is how students can individually identify their own learning style.

This tool, known as ILS, *Index of Learning Styles* (Soloman & Felder, 1991) is used mainly to get to know and understand the way in which the students currently learn. It has been proven that the ILS provides reasonable evidence to be considered a valid and reliable instrument to evaluate learning styles (Litzinger & Sang, 2007; Felder & Spurling, 2005; Zywno, 2003). Figure 6 shows an average of the answers as results. In each category the highest incidence is marked with blue and the lowest in red.

Results indicate that students (at least from this group) are predominantly active, sensory, visual and sequential. This can be an indicator that virtual laboratories aid in the learning process of our current students. In other words, it favors the current predominant learning styles.

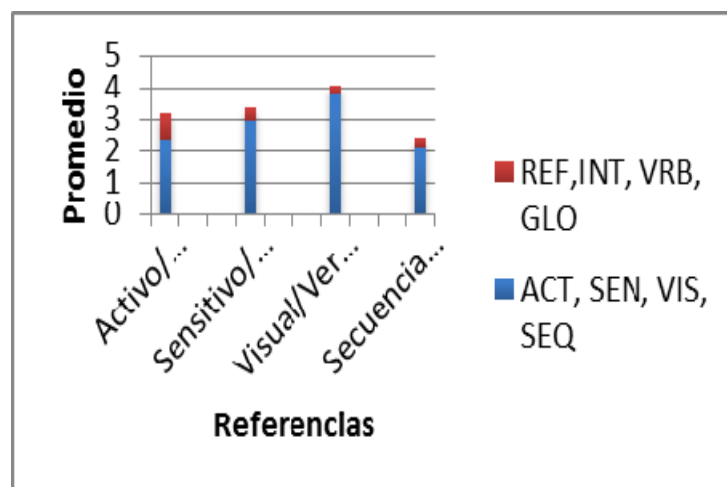


Figure 5: Graph showing the average obtained by the group in each learning style.

3.1 Analysis of the students perception regarding their own learning using this educational model

A questionnaire was conducted with the purpose of gathering information on how the students feel regarding this learning model. The survey was applied to 100 students, of which 94 answered it. The questionnaire was made up of 4 questions and the results are the following:

Question 1: Did the use of the remote laboratory help you to understand the concepts? Why? 95.5 % of the students answered "yes". All the comments regarding the remote laboratory were positive. Some of the comments were the following:

"There are some industrial processes we don't know, but the remote laboratory can give us an idea of how they work".

"It's simpler to watch a tank filling up and emptying up in real time and having to imagine it all".

45 of 94 students mentioned in their answers the word "imagine" in a context where it appears as a limitation to learn about industrial processes they are not familiar with. This can be indicative of how important it is for students to be able to "visualize" what they are learning.

Furthermore, when teaching an engineering discipline to students that are not familiar yet with industrial equipment and environments, it is harder for them to use their imagination, since it's something they have never seen before. Some answers pertinent to this issue were:

"It helps me to remember".

"You can relate the theory with the practice".

"Using the remote laboratory is more entertaining".

Question 2: Did you learn more than you expected using the remote laboratory? 80.7 % of the students answered affirmatively. All the comments were positive, including:

"I was able to understand more easily".

"We practiced more with the equipment in less time".

"I paid more attention to the problem".

"It's easier to understand chemical processes when you are observing them".

"I learned of the importance of calculations in real applications".

Question 3: Did the remote laboratory help you be more engaged and participative in class?

88% of the students answered affirmatively. All the comments in relation to the remote laboratory were positive. Some of the comments were the following:

"It does help because it makes the class less monotonous and more engaging".

"It helps us be able to do more activities".

"I would like to see a real full industrial plant in this version".

"It helps us to not just listen, but also to observe and practice".

Question 4: Write your comments regarding the laboratory.

This was the last question, and there was only one negative comment by a student, who wrote:

"I prefer learning the theory first".

On the other hand, the other 93 students who answered the questionnaire mentioned only positive aspects of using the laboratory. Some of the comments were:

"I loved it".

"It was a great experience, because first we learned the real thing and then the practice".

"If we go to the lab we waste a lot of time; instead, here we can see the teacher explanation and the real process with the remote lab all at once in the classroom time".

4 Conclusion

There have been studies that document the effect of sophisticated technology systems on the teaching-learning process, like the case of remote laboratories, which have shown an increased teacher-student interaction, collaborative work and, more importantly, greater interaction with the equipment and the experimental development and analysis of the data (Zywno et al., 2009). This can also promote the appropriate environments to develop practice communities, according to the theory proposed by Wenger (2002).

In general terms, it has been accepted that laboratory practices and workshops are activities that favor students' learning, since they provide with an opportunity to connect theory with real world practice (Laurillard, 1994; Mejías & Andújar, 2012).

Some of the additional benefits of remote laboratories, according to some of the comments from the students, are: it helps them remember and gather information about a process, it can be fun, and students are able to observe the physical phenomenon in the classroom (all under remote control).

Motivation is another important aspect of learning, which allows students to feel engaged in the process. It is probably one of the most important aspects the teacher has to keep in mind when giving class. In this regard, and according to the students' perception, the remote laboratory was new, didactic, fun, easy to observe and understand, and the students feel they are having fun learning.

All this makes us think that an educational model of this kind, which also follows the Tec 21 educational model, could pioneer a teaching-learning style and process for teachers and students that can evolve into a learning environment not only more appropriate to our age, but also a more meaningful one.

5 Future Research

The Tecnológico de Monterrey System and the Tec 21 Model state as part of their vision: "to create leaders with an entrepreneurial spirit, human sense and internationally competitive". Following this line, it is considered that the most valuable aspect of this educational contribution, on short and future term, is:

1. Developing the concept of the present educational model to include other areas and disciplines of the institution. An idea is currently being developed jointly with other colleagues for the Math I and Differential Equations courses. A new prototype is also being developed with our Chemical Engineering and Electric Engineering colleagues called NOVUS 2013.
2. Sharing with other colleagues and teachers, and develop the collaboration, not only within the institution, but also with other universities for the development, transference and dissemination of our educational advancements.

6 Acknowledgments

We thank the collaboration of Dr. Manuel Macías in the creation of the remote laboratory. We are also thankful of the System's Academic Vice-presidency and Campus Monterrey's Academic Presidency, for their unconditional support at several points in the development of this model. We thank Dr. Jaime Bonilla from the Engineering and Architecture School, who supported and championed presenting this work on an international forum. Lastly, the support from the

Center for Teacher Development and Educational Innovation (CEDDIE) has been a key to keep developing and collaborating with teachers on this educational innovation.

Special thanks to the students and teachers that participated. From left to right: Agustín Pizarra (MT student), Dra. Darinka Ramírez, Dr. Manuel Macías, Agustín Carranza (IEC student) and Alejandro González (IQA student)



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POSTER SESSION

Tallerine: a hands-on course for motivating freshmen for Electrical Engineering

Alvaro Giusto *

* Facultad de Ingeniería, Universidad de la República, Montevideo, Uruguay

Email: alvaro@fing.edu.uy

Abstract

The Electrical Engineering (EE) program of Universidad de la República faces several challenges regarding its freshmen generation: scarce visibility of the EE program, serious difficulties with student motivation, social integration and evasion. This situation motivated the offer of a new freshmen course named Tallerine by the first time in 2013. Tallerine (acronym of Introduction to the Electrical Engineering Workshop) is an active learning activity where the students develop team projects in several EE areas. The main goals are: motivate the students, stimulate their creativity; integrate them socially; that the students identify themselves with the University and the program; and let the students know the objects, topics, methodologies and actors of the EE program. The experience was very successful, exceeding our previous expectations. The course was closely monitored. This paper describes the methodology, the results and the key factors we identified in the development of the experience.

Keywords: freshmen courses; team based learning; electrical engineering; active learning.

1. Introduction

This paper describes the first experience of the course Tallerine (Spanish acronym for Introduction to the Electrical Engineering Workshop) at the Electrical Engineering (EE) program of the Facultad de Ingeniería, Universidad de la República, Uruguay. Tallerine is an active learning activity where the freshmen students develop team projects in several EE areas. It is described the motivation, the methodology, the first occurrence of Tallerine (first semester 2013), and the results.

2. Motivation

Uruguay faces a strong scarcity of Sciences and Engineering graduates, in all areas and levels, which constitutes a bottle-neck for the country plans aiming to develop the production, the culture and the knowledge. This scenario is not, of course, exclusive of Uruguay, Knight, D. W., Carlson, L. E., Sullivan, J. F. (2007), *Alonso Tapia, J. (2001)*. However, the Uruguayan scenario has some features that is necessary to describe.

In Uruguay 400 engineers graduate each year, equivalent to a graduate per 8000 people. This figure is sensibly inferior to the region's rates (6700 for Argentina, 6000 for Brazil, 4500 for Chile and Mexico) and very inferior to the rates in developed countries, near to 2000. The job market for engineers and technicians has zero unemployment and the demand is often unsatisfied with adverse economical and social consequences.

A distinctive characteristic of the Uruguayan educative system is the absence of formal limitations to the access to the public university system in most areas, including Sciences and Engineering. Any student completing the secondary cycle is free to access the public University. However, the number of freshmen students of Engineering does not increase and the indices of evasion are quite high. Figure 1 shows the graduation and admission trends for the EE program along years 2008-2011. The graduation/admission ratio is about 40%.

The freshmen feminine population is about 20% evidencing a strong opportunity to increase the admission and diminish the genre discrimination by trying to change the existent cultural bias.

The EE program nominally lasts 5 years and has a generalist, credit-based, flexible curriculum. The program has received twice the official Mercosur accreditation in 2006 and 2011. The background on Physics and Mathematics is mostly concentrated in first 4 semesters, common for most of the engineering programs. The basic technological content is concentrated in semesters 5 and 6. Specific technological contents are in later semesters which open the offer along several professional lines in EE (telecommunications, power systems, electronics, etc.).

The organization of the program basically delays the first technological contents to the 5th semester, delaying also the first project-based learning activities. This scenario results in:

- a scarce freshmen visibility of the EE program, among all the Engineering programs (mechanical, civil, quchemical, computer science, etc.);
- serious difficulties with student motivation, social integration and evasion;
- number of freshmen EE students descending from 240 to 120 in seven years.

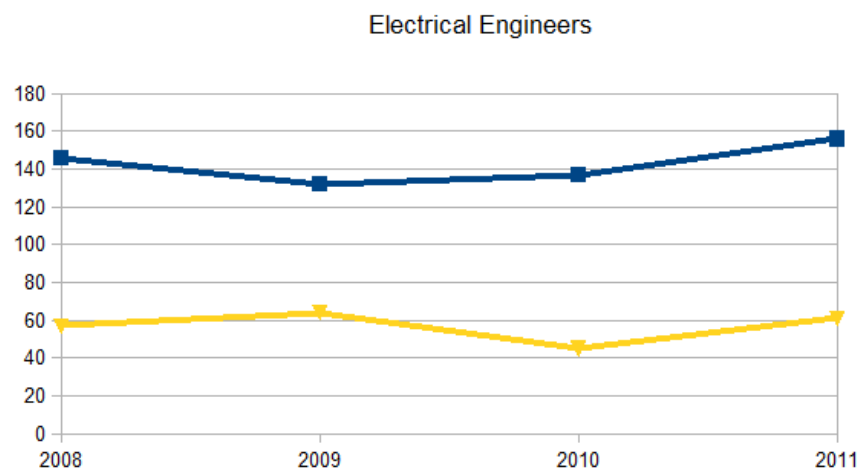


Figure 1 : Annual graduates (yellow) and freshmen students (blue) of the EE program.

This situation motivated the offer of the new freshmen course Tallerine by the first time in 2013. Tallerine (word that in the local Spanish language also has funny connotations strongly contrasting with the usual university formal language) is an active learning activity where the students develop team projects in several EE areas. The main goals are:

- motivate the students,
- stimulate their creativity;
- integrate socially the students;,




- that the students identify themselves with the University and the program,
- let the students know the objects, topics, methodologies and actors of the EE program.

3. Methodology

In few words the methodology is as follows.

The group is organized in teams composed by approximately 6 students. Each team is to develop a project along a semester of about 15 weeks.

Several (five in 2013) EE projects are offered whose main attributes are:

-  imply the building of a prototype;
-  are representative of the main applications of EE;
-  have ludic and motivating aspects.

The projects developed by the students are exposed in a final public event, and by the elaboration and publication of a short video.

The students work in interaction with teachers and with EE students that play the role of teacher-assistants (T.A.) who participated in the experience voluntarily. It is intended that the interaction with the T.A. (young persons like them, but with some experience with the school and the program) be a stimulus for all of them.

The course schedule includes some initial classes, introductory to the basic objects to be manipulated (basic electronic components, programming, electronic devices and tools, etc.) and a schedule of intermediate deliverables.

The grading is individual although, of course, take into account the team performance. It is based on the deliverables (written reports, presentation, prototype), class observations and coevaluation.

The key tools of the methodology are discussed next.

Motivation. It is the main objective to achieve and also the main educative tool. Motivation was closely monitored by the daily teacher-student contact and through surveys specially designed with this objective. Motivation was also the main tool to organize the team of teachers and voluntary teacher-assistants.

Team work. Our previous experience with active learning in Engineering, see e.g. *Belzarena, P., Giusto, A. & Randall, G. (2007), Belzarena, P., Eirea, G., Giusto, A. & Monzón, P. (2011)*, suggested a number of 6 students per team. It provides redundancy, enough work force to achieve some interesting technical goals, and the basic cell for social interaction and communication. The fair distribution of tasks between the team was observed by the teachers in each instance and by the co-evaluation, described later.

Challenging projects. The proposed projects were frankly challenging for the students, given their previous background. This fact is strongly motivating when properly handled. The lack of background

was circumvented by several teaching tools: introductory material, tutorial exercises, black boxes in electronics and software, etc. The objective was *to work with* these devices instead of *to analyze* them or *to model* them.

Closely controlled course. Teachers had to be careful with several details potentially able to frustrate students along the course. One aspect that deserved a lot of attention was the level of difficulty of the different tasks in order to be reached by the students with a heterogeneous and partially unknown previous background. The projects and the tools provided were thought in a modular way in order to tune their extension and difficulty during the semester. Some projects were extended because primary objectives were surprisingly reached very fast.

Technical communication. The student teams were asked to present their advances at least twice, with computer presentations and prototype demonstrations. These instances provided feedback about the ongoing projects for students and teachers. Written reports were also asked and the elaboration of a video per team. The videos had two guidelines: a hard limit of 5 minutes and the warning that they will be public on Internet. Considering that the elaboration of the video was the last activity of the semester, they were advised to relax and enjoy the experience to publish their work on the net.

Tallerine communication. The course was not mandatory in 2013 and the students could see it as a mere option. Thus, an intense communication was developed in order to let the students know about Tallerine. A set of posters were printed and posted on walls of the building, all of them trying to transmit the ludic nature of the course and to break the quite formal language in use. During the course, two on line tools were used. The University education site (<https://eva.fing.edu.uy/course/view.php?id=405>) was employed for formal communication and news, and the facebook site of Tallerine (<https://www.facebook.com/Tallerine>) was employed as a repository of pictures, videos and a way to maintain the students motivation.



Figure 2: Tallerine posters (left: "My name is Tallerinator. I was created in 2053. I'm here to help you")

The communication of Tallerine was also balanced with respect to the genres including masculine and feminine known images (although the selected two poster included in this paper are showing only masculine images).

Coevaluation. At the middle and the final of the semester a mandatory form has to be filled by the students. The questions asked the student about the punctuality, the attitude, creativity and the respect for the team agreements of each member of the team. These data were processed very fast and the feedback, student by student, was put in knowledge of the teachers. The average rate received from their colleagues was also communicated to each student. This tool was very helpful to encourage the right attitudes in a work force and prevent an unfair distribution of tasks and responsibilities inside the student teams. The coevaluation form was designed along references *Alonso Tapia, J. (2001), Míguez, M. & Loureiro, S. (2012)*.

The projects offered in 2013 were:

Analogic synthesizer ("Sintetizador"). Each team must build a electronic musical instrument, departing from schematic diagrams and basic principles of different electronic modules: oscillators, amplifiers, filters, modulators, etc.. Each team had to:
design the layout and build the printed circuit board (PCB);
build each circuit (to cut and drill the PCB, welding the components);
test and debug each circuit;
synthesize a sound chosen by the team (e.g. the sound of a motorcycle, an alarm, etc.).
Finally, each team had to design and build a sound controller, e.g. a controllable device that helps to play the sound.

The controllers built were five different devices ranging from an optical harp to a kind of a guitar based on a linear resistance. We discovered the artistical skills of several of our students.

Othello game ("Otelo"): Each team had to program a small micro controller Arduino in order to manage an 8x8 led matrix, communicate with a similar device and implement a strategy to play the Othello game. The hardware (Arduino card and a PCB with the led matrix and associated circuitry) was supplied. The students work was entirely on the game strategy and the programming. The routines provided by the teachers implement the basic manipulation of the led matrix, the PC-Arduino communication and a routine that returns the possible places for the next move. Teachers provided a first benchmark (nicknamed "the monkey player") that simply chose the moves at random. A second teacher's benchmark, more competitive, was provided later. Students investigated on Internet and designed game strategies to play against the monkey player and other opponents. The project ended with a competition between the students teams and the teacher's strategy.

Cell phones with Android ("Android"): the teams implemented routines for the management of the basic peripherals of a smart phone (camera, display, audio, device attitude) to play with them and implement basic games. The teams began making programs to implement different games (bouncing balls, mazes, etc.) and signal processing routines. The final projects, at the end of the semester, include an interactive maze (the user can draw a maze on a paper, take a picture and use it to play on the cell phone), programs that directly upload pictures on Internet and several kind of

games based on the attitude sensor and the tactil display.

This project was the most challenging from the technical standpoint. Some teaching procedures and materials are been revised for 2014 in order to turn easier the first approach for students lacking previous experience on programming.

Solar energy system ("Solar"): the teams had to build a battery charger fed by a photovoltaic panel. A 6V battery and a 17V, 12W photovoltaic panel was provided, as well a schematic diagram of a linear voltage regulator that can charge the battery from the solar energy. The project included an initial set of very interesting workshops about renewable energy, the design and construction of the PCB and the testing of the final circuit. This project, the most technically simple, was as effective as any other to keep the students motivation all along the project.

Simon game ("Simon"): Students implemented the classical game with an electronic plaque of configurable logic, the Terasic's DE0. The blocks of logic were very simple and the introduction of the studients to this technology was made very efficiently with a set of three tutorials. The implemented game was based on three colors and switches, instead of the four of the classic game. A VGA output allows to observe the game on a computer monitor.

The 2013 experience

The first experience was, *a priori*, plenty of uncertainty. The teachers team had a significant experience about teaching students with three or four years of university education, see e.g. Oliver, J. P.; Haim, F., (2009). There was no previous experience of our team on teaching freshmen with the significant differences in maturity, background and motivation.

There was no previous experience in the program with a teaching methodology aimed to build devices and prototypes without a very solid background on Physics, Math and modeling skills. Despite of these uncertainties, the offer was not intended to be a pilot program for a reduced target: Tallerine was offered to the complete generation of EE freshmen students: about 150.

The main tool to cope with the uncertainty was the close monitoring of the learning process and the pre-design of the projects in a modular way. Projects were conceived in such a way that they can be enlarged or simplified in accordance to the students response.

Each student chose his/her first and second preferred project. Vacancies were assigned taking the students preferences into account and trying to balance the five projects each with about 30 students.

The course began with a first magistral class (the unique, by the way) to welcome the students, explain the methodology, the schedule and the basic rules. Its main objective was to be sure that they understand the basic fact that Tallerine is a course *to do things* and *not to listen*. The message was explicit and completely in line with the previous publicity. During the first class a survey was done in order to collect some data and measure the initial enthusiasm with the proposal:

Genre	Masculine: 104	Feminine: 24	
Age	17-18 years old: 75	19-20 years old: 33	>20 years old:19
Year of admission in Univ.	2013: 88	2012: 27	<2012: 13

The survey ask the grade of enthusiasm with the course:

Very enthusiastic	Enthusiastic	Mid enthusiasm	Little enthusiasm	No enthusiasm
41	70	16	1	0

These results show that the students like of the basic idea of Tallerine and the communnication and its language were very efficient for conveying the main messages.

On the 7th week of the semester the survey asking directly for the student enthusiasm with the course was repeated. The results, broken down by project, are shown in Figure 3.

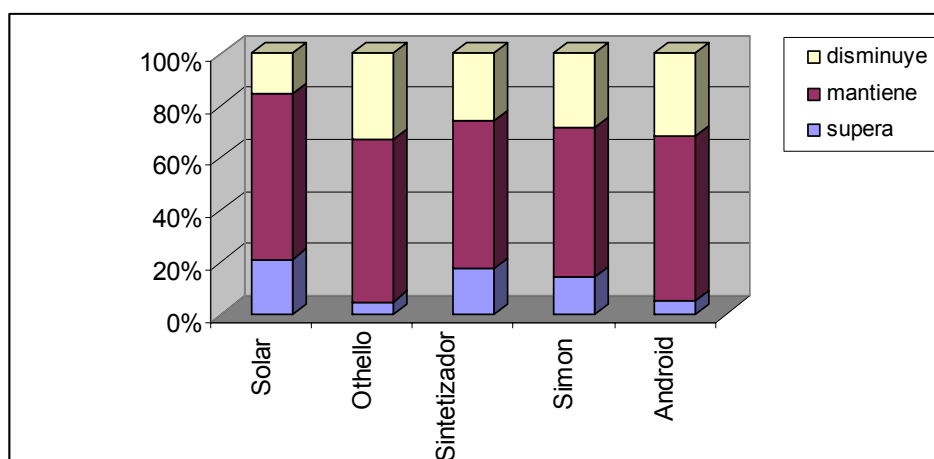


Figure 3: Intermediate survey, by project. Left to right: Solar, Othello, Sintetizador, Simon and Android. Skyblue: students who feel more enthusiastic than initially; violet: students with the same enthusiasm; white: students with less enthusiasm.

Figure 3 shows that the project Solar was very effective in keeping (and increasing) the student motivation the first part of the semester. Projects Othello and Android show that several students lose part of their initial enthusiasm. In particular, in these weeks and projects the students made their first experiences with programming, compiling and debugging, some defiant tasks that yield their results later. It was very important to get timely these data and share it with the teachers team.

4. Main results

We can observe the results of the course through its main products and also through the evaluation the students did through a final survey, described below.

The projects were presented in a public event at the final of the semester. There were demonstration of musical instruments, photovoltaic battery chargers, games and application on Android devices, Otelo competitions, implementation of Simon games in a quite festive event. Pictures of the event can be seen at Tallerinefb (2013).

The videos elaborated by the students have shown to be an excellent tool for socializing, describing the main ideas and the project. Is also a very valuable way to freely express the students opinion and mood about the course.

The videos Massonier et al (2013), Garcia, G. et al (2013), Hernandez, G. et al (2013) are particularly descriptive of the course methodology, as seen by the students. The reader can look all the videos on TallerineVideos (2013). They are spoken in Spanish, but most of the message is not verbal. Versions subtitled to the English language will be presented at the Workshop.

5. Final survey

The final survey was broken down by project. This fact is very important because, although the methodology was common, each project has a big amount of autonomy with the teaching materials, schedule and technical details of the project. Figures 4 to 9 show the results for the Android project. It is good to emphasize that the differences between projects were frankly minors and the results shown in Figs. 4-9 are representative.

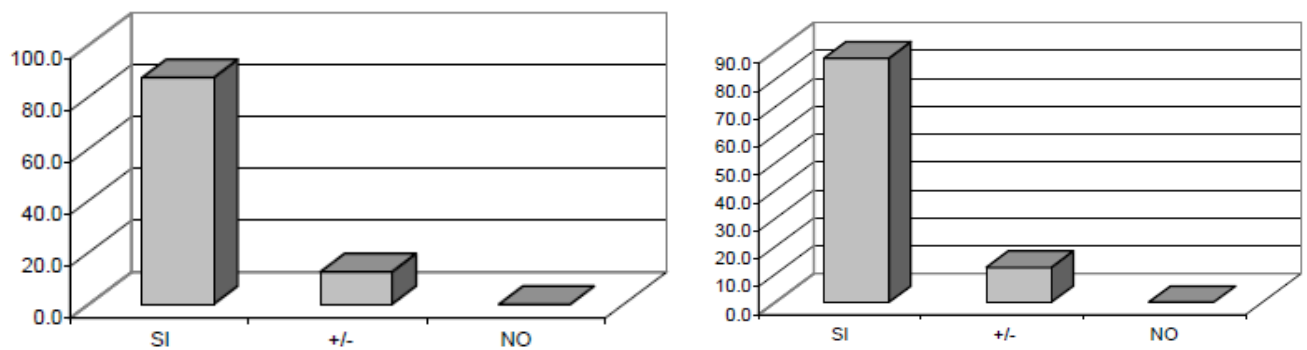


Figure 4: Left: "Did you participate with enthusiasm?". Right: "Did you find the methodology adequate?". Answers: Yes, more or less, No.

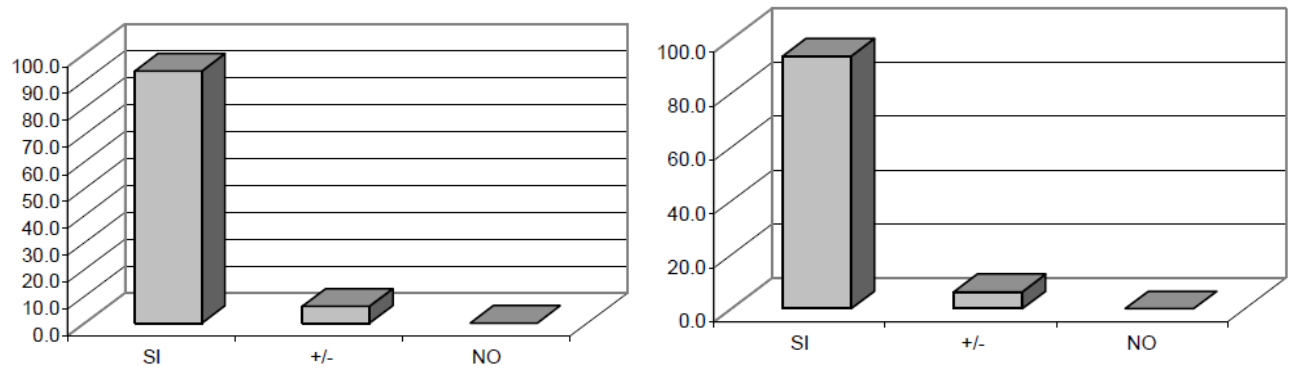


Figure 5: Left: "Did Tallerine improve your initial perception of the methods and contents of the program?". Right: "Was Tallerine useful for helping you to integrate with your class mates?".

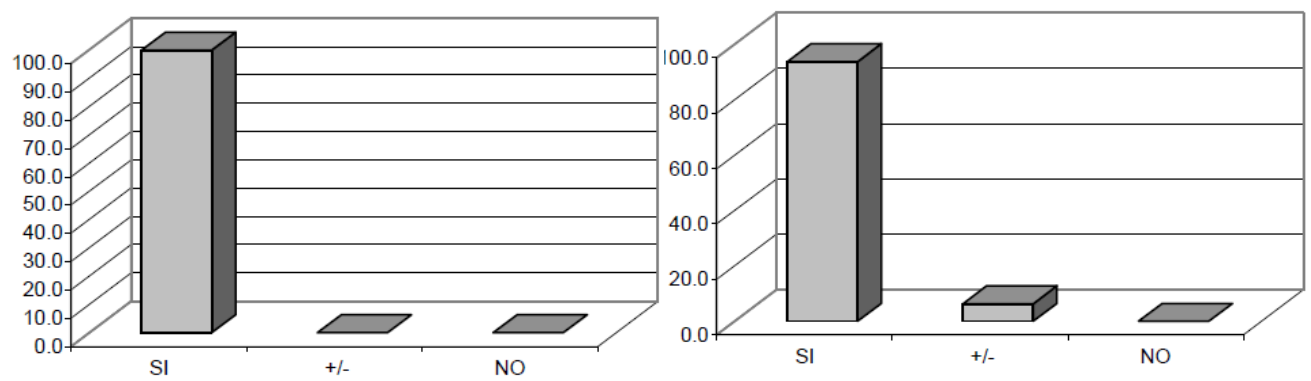


Figure 6: Left: "Did you find comfortable working in a team?". Right: "Did your team work reasonably well?".

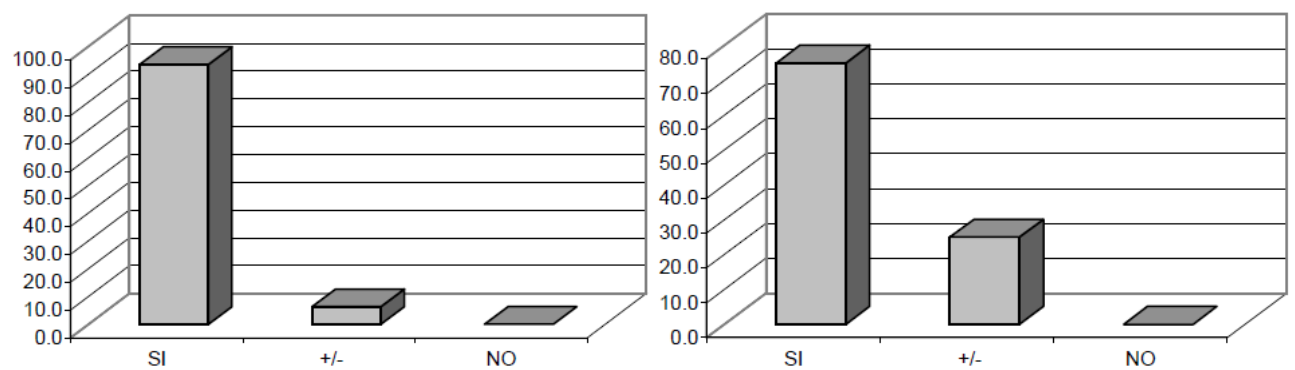


Figure 7: Left: “Did the teachers or assistants answer the questions risen?”. Right: “Was the support material suitable?”.

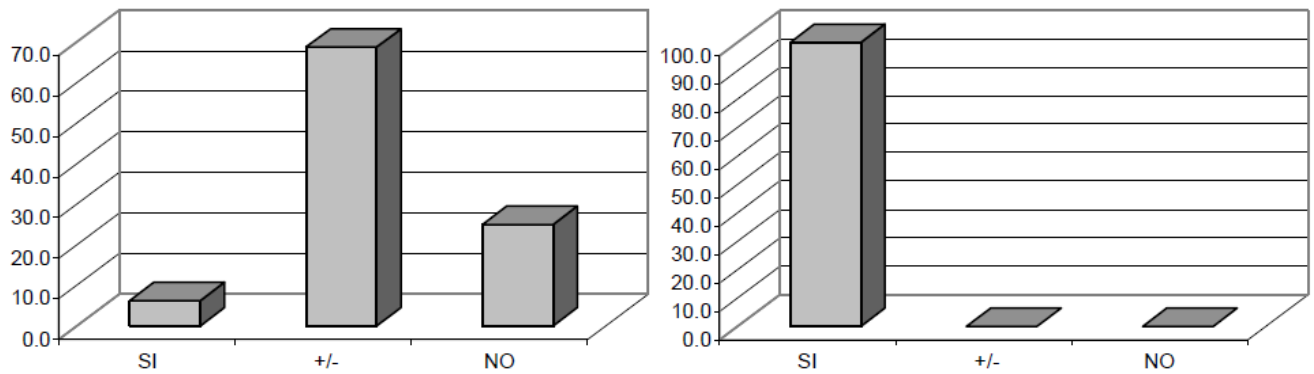


Figure 8: Left: “Did Tallerine turned more difficult to follow the rest of the semester' courses?”. Right: “Would you recommend Tallerine to other students?”.

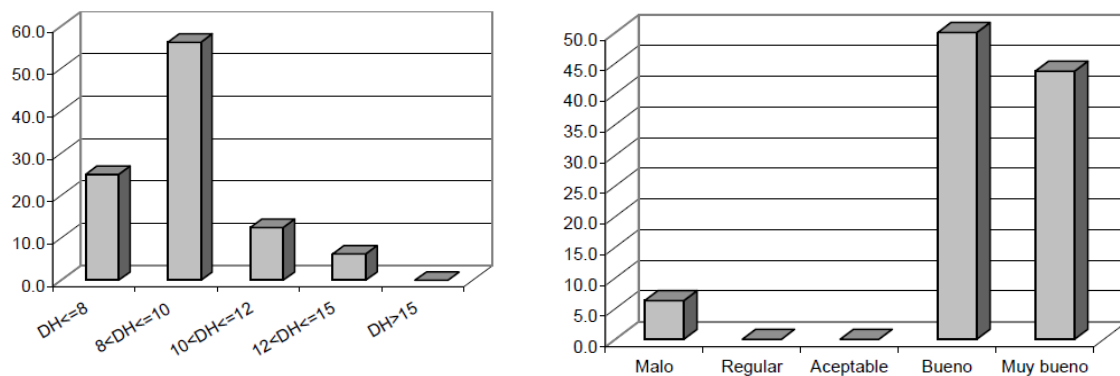


Figure 9: Left: “How many weekly hours (DH) you dedicated to Tallerine?”. Right: “Which is your global opinion on Tallerine?”. Answers: Bad, Regular, Acceptable, Good, Very good.

One of the concerns of the teachers team was the students weekly time necessary for Tallerine. A priori there was high uncertainty about this. The result was very good, with a median near to the nominal 10 weekly hours previously planned.

Conclusion

This document is brief description of the first experience with Tallerine, a hands-on freshmen course for motivating and introducing students to the EE program. Despite the strong challenges and the lack of specific experience, the course achieved very well our expectations and show to be very

successful. Some key aspects of the teaching methodology were identified as the main tools for the results obtained: teachers motivation and rapport, quick feedback, suitable communication, close monitoring and the employment of suitable surveys for measure students motivation and team performance. The documentation of the projects via the elaboration of short, public, videos was a true finding very helpful, in addition, for later divulgation facing the 2014 issue.

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Innovation and Entrepreneurship to attract students to engineering

Mauricio Duque⁺, Catalina Ramírez^{**}, José Tiberio Hernández^{***}, Alba Ávila⁺

School of Engineering, Universidad de los Andes, Bogotá, Colombia

⁺Department of Electric and Electrical Engineering

^{**}Department of Industrial Engineering

^{***}Department of System and Computing

Email: maduque@uniandes.edu.co, mariaram@uniandes.edu.co, jhernand@uniandes.edu.co, a-avila@uniandes.edu.co

ABSTRACT

Throughout a couple of semesters we have designed the course named Science, Technology and Innovation at the University of the Andes. This course is offered to engineering and non engineering students. It aims to bring innovation and technology-based entrepreneurship to students of engineering and other disciplines. As the conceptual approach comes from engineering, it has attracted different disciplines in engineering that are complementary to field future work. Through innovation case analysis, based on technological developments, the students identify characteristics of innovation projects, success and failure factors and are able to distinguish opportunities to learn about active innovation and active entrepreneurship experience. It is expected that at the end of the course, the students have achieved a sufficiently holistic innovation system and the role of different professions in it, so that they can broaden the understanding of the great challenges facing the country and therefore be able to evaluate different solutions proposed in strategic sectors for the country. The engineering students (and those who are not) work projects they consider to be innovative and are able to generate venture. In different workshops they have to discuss, select and propose a business model around these ideas. This paper presents the structure of the activity of selection and development of a potentially innovative idea by an interdisciplinary team.

Keywords – innovation, entrepreneurship, interdisciplinary

1. Introduction

To promote abilities and attitudes oriented towards innovation and entrepreneurship has become indispensable nowadays in any educational institution that wants to be state-of-the-art. However, this is an area in which, more than contents, work on capabilities is required. This presents a challenge given that the problem cannot be easily solved using the traditional formula of lectures and workshops on applied exercises. New approaches to teaching are required. At the University of the Andes, the challenge of finding a solution has been supported in three main pillars:

- From the curricular point of view, propose a “minor” on innovation for the students who are interested. The courses included in this minor are also offered to students outside the option.
- Courses based on active learning using models of case studies, projects and workshops.

- Activities leading to the visibility and confrontation of ideas and developments with the environment, in the framework of fairs, exhibitions and public presentations to people outside the university.

Based on these pillars, a course (Science, Technology and Innovation) has been developed throughout the past years. This course is the introduction to the minor, and its format has varied taking into account experiences in its development and application.

In the 2013 version, the course proposes a format where the students have to undertake an innovation project, step by step, starting with identifying a problem that can be solved with technological innovations, up to the presentation of a business model at the end of the course to members of the innovation ecosystem external to the University. Additionally, in this course, students are exposed to talks with innovators and entrepreneurs and have to analyze business proposals from advanced students, that are presented in exhibitions and fairs. They are also involved in simulations of business rounds with invited external investors.

To develop the business model, the following have been used: 1- the canvas model (see fig. 1), 2- simulated business rounds with investors and 3- the construction of mental maps to help students clarify their ideas.

2. Description of Active Methodologies

2.1.Canvas

To guide the development of the business model, a CANVAS like the one illustrated in the following figure is proposed.

During the main part of the course the students work on the components of Value propositions, Customer relationship, Channels and customer segments.

When these components are coherent, the student groups proceed to develop the rest of the business model.

The Business Model Canvas

Designed for: _____ Designed by: _____ On: ____/____/____ Iteration: ____

Key Partners Who are our Key Partners? Who do we rely on? Whose help/resources are we seeking from partners? Which key activities do partners perform? Which key resources do partners provide? Which key channels do partners use? Which key customer segments do partners serve?	Key Activities What key Activities do our Value Propositions require? Our Critical-to-Success Key Activities? Customer Relationships? Channels? Key Resources?	Value Propositions What value do we deliver to the customer? What kind of customer problems are we helping to solve? What is unique about our value proposition? Which customer needs are we satisfying? Key Resources? Key Activities? Key Channels? Key Customer Segments?	Customer Relationships What type of relationship does each of our Customer Segments expect us to establish to maintain with them? How are we going to interact with them? How are they interacting with the rest of our business model? How easily can they be lost?	Customer Segments For whom are we creating value? Who are our most important customer segments? Key Resources? Key Activities? Key Channels? Key Customer Segments?
Key Resources What key Resources do our Value Propositions require? Our Critical-to-Success Key Resources? Channels? Key Customer Segments? Key Activities?		Channels Through which Channels do our Customer Segments want to be reached? How are we reaching them? How are our Channels integrated? With the cost and benefit? With the value we create and deliver? How are we integrating them with customer relationships?		
Cost Structure What are the most important costs inherent in our business model? Which key Resources are most expensive? Which key Activities are most expensive? Which key Channels are most expensive? Which key Customer Segments are most expensive?		Revenue Streams For what value are our customers really willing to pay? For what do they currently pay? How are they currently paying? How would they prefer to pay? How would they prefer to pay? How would they prefer to pay?		

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Figure 1: General Canvas

2.2. Simulation of investors game

The work groups are confronted in a game in which they simulate their participation in an investors business round. In not more than 5 minutes, they have to answer the investors the main question: "Why do you have to invest in my idea?" Some of the questions associated to this dynamic are:

- What do we do that people need or want?
- Who is our customer?
- How do customers find out about our products?
- What distribution channels should we consider?
- How much is it worth to the customer? (It's not only the price, but the value that the final client sees in the product, such as time saved, cost of opportunity, peace of mind, etc., and how to associate a number to that value.)
- What pricing model should we choose? (How are we going to monetize the value the client finds in our product?)

2.3. Construction of collective conceptual maps

With the goal of clarifying the students' ideas, activities are developed geared towards generating maps of ideas. (see figs. 2 and 3).



Figure 2: Conceptual maps



Figure 3: Students at work

3. To Excite with Innovation and Entrepreneurship

At the end of the semester, students should be able to observe and analyze innovation projects both from their own and other disciplines. That is why they participate as evaluators in the end-of-semester Fair in Innovation and Entrepreneurship. Around 150 projects from all the University participate in this fair. The format to analyze their companions is the following:

CATEGORIA		Description	Grade
15%	Idea	8-10: It's a clever idea to solve a real problem. 6-8: The idea is new. It is an incremental innovation. 0-6: An existing version improved designs and solutions	
20%	Design	8-10: It can be inferred that the prototype will be able to perform and maintain its functions in routine circumstances 6-8: suitable, capable of performing the basic functions Design. Some modifications are necessary 0-6: The product is not feasible as planned.	
25%	Prototype	8-10: The prototype / demo / concept is very good quality. It is self explanatory and very easy to use. 6-8: It is sturdy and functional. The project is well researched 0-6: The implementation can be improved, but the prototype / demo / concept aims to meet objectives. The project lacks technical work and / or theoretical. A new user require much explanation to understand the prototype / demo / concept.	
15%	Analysis	8-10: It involves the application of concepts and methodologies of the discipline in the design and implementation 6-8: We have applied some concepts and methodologies of the discipline in the design and implementation 0-6: There were very few applied concepts and methodologies of the discipline in the design and implementation	
10%	Oral Skill	8-10: Able to converse fluently about design. Da thorough explanation of the effectiveness of the prototype / demo / concept and weaknesses and suggests ways to improve it. 6-8: Understanding enough design and implementation and discusses the project's ability to meet the project objectives. 0-6: It is unwilling and only provides a general description of the project.	
15%	Poster	Rate from 1 to 10 the quality of the presentation taking into account the following aspects: Visual aids, clarity of content, creativity, grammar and coherence.	
GLOBAL RATING			0,00

Project Name

Referee

mail

Comments

REGISTRAR

Figure 4: Project evaluation format

A sample of the results of the perception of the characteristics of innovation and entrepreneurship of a given the project, evaluated according to the criteria expressed above is:

Idea (10%)	Design (20%)	Prototype(25%)	Analysis(15%)	Oral skills(10%)	Poster (15%)	Final grade
8,679872881	8,725	8,628177966	8,903389831	9,327966102	9,038347458	4,412452331

In the mentioned fair, the projects were evaluated by other students and teachers.



Figure 5: The Fair

4. Student course perception

The following table reflects the perception of the students with respect to the 2013 course.

Questions	
1. Does the course meet your expectations?	3,92
2. How much am I interested in innovation?	4,38
3. How much am I interested in entrepreneurship?	4,27
4. Did this course change my conception about innovation?	4,31
5. Did this course change my conception about entrepreneurship?	3,34

Figure 6: Perception of the 2013 course

5. Course structure for 2014

The evaluation of the course shows some aspects that have to be improved:

- 1) The 2013 students' assessment is difficult to grade individually because most of activities are done in teams.
- 2) Assigned lectures are not used as intended in the course design.
- 3) Final projects reflect some misunderstandings about innovation despite the activities, lectures and workshops included in the course.
- 4) Some groups look for innovative solutions to problems that have not been well defined.

In order to improve the course, the following structure was proposed:

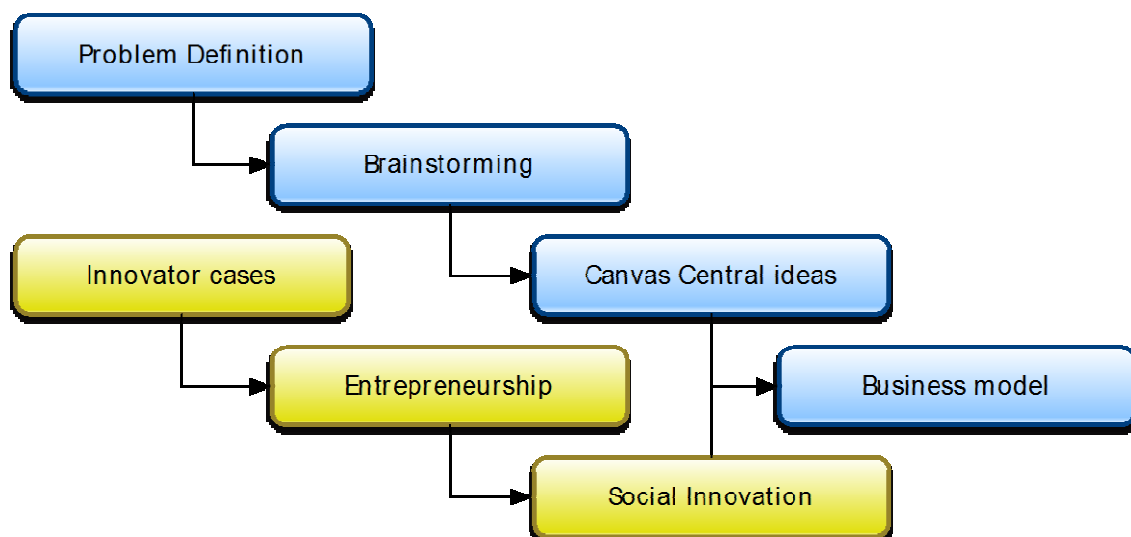


Figure 4: Course's new structure

6. Conclusions

Innovation and entrepreneurship have become more and more, two crucial aspects of the multi-disciplinary work of the School of Engineering and of the University in general. The course described belongs to the minor in Innovation with Technology where projects are developed during the semester culminating in the innovation and entrepreneurship fair where everybody, students and teachers alike, simulate offerings of ideas as solutions to different problems.

As can be seen in the different active methodologies, students understand the importance of simulating the entrepreneurship of an innovative project and of having to specify a design and a prototype. This not only produces excitement in having to apply their disciplinary knowledge, but also in actively learning from the others.

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Attracting Girls and Boys to Engineering Programs through Non-Formal Learning Environments

José Arthur Martins*, Elisa Danda de Oliveira*, Livia Doncatto Tessari*, Sara Andrade de Oliveira*,
Odilon Giovannini*, Valquíria Villas-Boas*

*Centro de Ciências Exatas e Tecnologia, Universidade de Caxias do Sul, Caxias do Sul, RS, Brazil

Email: jamartin@ucs.br, elisadanda@bol.com.br, lili_dontes@hotmail.com, saaoliveira1@gmail.com,
ogiovannini@gmail.com, vvillasboas@yahoo.com

Abstract

It is possible to awaken scientific curiosity of young people through new learning environments in their school context avoiding the reproduction of information from traditional classes. The process of teaching and learning in non-formal learning environments may help in the understanding of theoretical concepts. This paper presents the Scientific and Technological Rally, an activity of the "UCS-PROMOPETRO: New Challenges for the Engineer of the Future" project, a non-formal learning environment, whose main objective is to integrate the high school students to the university and encourage them to choose an engineering program when they go to the university.

Keywords: high school, attracting young people; interdisciplinarity; non-formal learning environments

1 Introduction

According to Fernandes (1998), most students consider science classes as a course full of names, cycles and tables to be memorized. So the question that arises is: how to attract students to study science and how to stimulate their interest and participation? The answer, of course, is not simple, nor is there a ready recipe. However, it is necessary to look for solutions, ponder the problem and exchange experiences.

To propose teaching-learning methodologies that aim to stimulate student interest in science is a way of promoting a taste for science and technology, taking into account the previous ideas of the students and the skills they have to relate the concrete and/or abstract entities involved in the established relationship. Activities to build and reformulate models can be a good option in an attempt to meet the contemporary requirements for teaching science in engineering.

It is possible to awaken scientific curiosity of young people through new learning environments in their school context, avoiding the reproduction of information from traditional classes that prepare students more for the tests rather than involving them in the process of learning and in the thrill of discovery.

Through interactive and significant activities, it is possible to engage high school students and motivate them to areas of science and technology. In this context, the project "UCS – PROMOVE: The Engineering of the Future", also known as ENGFUT (Villas-Boas & Martins, 2012; Villas-Boas, 2010), sponsored by the University of Caxias do Sul and financial support from FINEP (Brazilian Agency for Innovation). This project started in 2008 has as its main purpose to strengthen the teaching of science and awaken young people's interest in engineering. In this project, the pedagogical strategy used in the development of activities is Problem Based Learning (PBL).

Problem Based Learning (PBL), with the focus that we know today, was established as a teaching strategy in the late 60s at McMaster University in Canada, and, shortly after, in the University of Maastricht in Netherlands (Savin-Baden and Major, 2004). Since then, many universities have adopted this methodology, initially in undergraduate programs in the health area, but after in different areas such as engineering programs, economics, psychology, architecture, physics, chemistry and biology, among others.

In Brazil, the Marília Medical School and the School of Medicine from the State University of Londrina were the pioneering institutions in the implementation of PBL methodology in the curriculum in 1997 and 1998, respectively. Currently this methodology is widespread among Brazilian universities mainly in Brazilian medical schools and in some engineering schools.

PBL can be understood as a strategy or methodology of teaching and learning that aims to build knowledge in the context of interdisciplinary problems (Delizoicov & Silva, 2005; Graaff & Kolmos, 2007)

This strategy has as main features: the fact it that always initializes presenting and discussing in small groups accompanied by a teacher-tutor, and from a problem previously prepared by a group of experts. These problems must always be contextualized, and in addition, the methodology assumes that the process is student-centered, is an active process, cooperative, integrated and interdisciplinary, oriented to the learning skills. The studies in the area of cognitive psychology, adult learning and neuroscience have provided the theoretical basis of PBL. These studies emphasize the importance of prior experience and active participation as key points to motivation and knowledge construction (Oliveira Filho, 2003)

In this context, the activities developed in the ENGFUT project are planned to give meaning and foundation to the teaching-learning process of science and for the application of theory in the solution of real problems, while articulating scientific, economic, environmental, social and political aspects and also to reinforce the important role of engineering in society and in the industrial and service sectors. This paper aims to present the Scientific and Technological Rally, an activity of the ENGFUT project, a non-formal learning environment, whose main objective is to integrate the high school students to the university and encourage them to choose an engineering program when they go to the university. This paper is organized in three main sections: the conceptual framework, the development of the activity and the final considerations.

2 Conceptual Framework

2.1 Formal, Non-Formal and Informal Education

There is no consensus on the distinction of the concepts of formal, non-formal and informal education. Different authors use the same terminology to explain different situations and different attributes are used in an attempt to conceptually delimit these educational modalities that allow, even without a precise definition, the understanding and the distinction of these terms (Colley, 2002).

The relation with the environment where the educational process takes place is commonly used to differentiate the concepts of formal, non-formal and informal education. However, other factors are used to make this distinction, such as the issue of the environment where the educational process occurs, the relationship between the subjects involved in the process, the existence of intentional teaching, the use of specific methodologies and techniques for the implementation, as well as, teaching procedures and learning evaluation, systematization and organization subject to the institutional guidelines, among others (Godin, 2002).

Vieira et al. (2005) define formal education as that occurs in formal education environments and non-formal education as the one that occurs in non-formal environments, but in situations where there is intent to develop teaching and learning. The circumstances where informal education actions occur can be considered, then, all those that do not relate to the objectives of formal and non-formal education, such as those that occur in the daily lives of people in their home, professional, leisure and entertainment environments, among others.

According to Garcia (2005), school education is the one where knowledge is systematized, which justifies its definition as formal education. Non-formal education has a territory and a way of organizing and relating itself in this territory of its own. In this context, it is not adequate to use instrumental and characteristics of the field of formal education to think, talk about and understand the non-formal education .

This aspect is important to reduce the confusion between these two forms of educational action. Otherwise, as reiterated by Garcia (2005) "it runs the risk of, as we think about non-formal education, having as parameter elements that commonly circulate in the formal education plan, tending to understand that from this, in a dependent and unreal way". This author also considers, in favor of non-formal education, that it allows a certain irreverence in dealing with issues of the educational context and with inherent relations to it, facilitating and enabling creativity.

As an example of non-formal spaces, one can point out the educational practices developed by museums, in terms of communication and scientific dissemination. However, their actions are often perceived as a reflection of formal education, approaching the school curriculum proposals, mischaracterizing, partly, their non-formal educational practice. However, we consider that non-formal education environments can be used to implement proposals of

formal education, as places for school extension, depending on interest, ability and autonomy of the teacher in the school to which he/she is attached.

The school practical activities developed in non-formal environments are given different denominations which may vary according to their nature, but that have in common their execution in a non-school environment. These include field classes, environmental education classes, environmental studies, field trips, external visits, excursions, guided tours, among others (Marandino et al., 2009; Fernandes, 2007; Jenkinss, 1999).

We also believe that non-formal education is complex in nature, being an open activity that is still under construction. Therefore, it has no ready and finished identity. It is a very diverse area, and this aspect is very interesting, because it allows, besides contributions from several areas, the composition of different cultural backgrounds, with diversity as one of its features.

2.2 Formal and Non-Formal Learning Environments

Learning can occur in different situations, and how it is organized and its quality depends on different aspects, including the place where it occurs.

The classrooms are seen as traditional teaching environments, which means that the environments outside the four walls of the school may be classified, according to Xavier and Fernandes (2008), as non-traditional learning environments. The classroom, as stated by these authors, is a physical space limited by the pedagogical relationship, but it is not the only area of educational action.

In an unconventional learning environment, the relationship of teaching and learning do not necessarily need to be between teacher and student(s), but among subjects who interact. Thus, the interaction can also be among subjects and concrete or abstract objects, with which they deal in their daily lives, resulting from this relation the building of knowledge.

The various non-formal environments have intrinsic properties that, in their different contexts, expose some direct or indirect relations with the content of school subjects, providing the dissemination of knowledge often not found in school environments.

The non-formal learning environments vary greatly in their characteristics and social functions, and may even not be primarily intended for learning. However, some of these spaces used in formal learning activities have actions associated with the non-formal learning.

Among the non-formal settings that can also be used for the development of formal learning activities, are included museums, urban recreational parks, botanical gardens and zoos, conservation areas, fairs and exhibitions, among others.

Spaces associated with the non-formal learning are the most used as extensions of formal educational practices. However, there are other environments, which can likewise be used as a "scenario" to formal education proposals, i.e., they can act as extensions to school activities, such as factories, shopping malls, food courts, quarry, mine, fishing ponds, clubs, and other large private and social organizations, as well as, public representations. Given these examples, we can conclude that these spaces may have simpler levels of organization, more personal and/or familiar, such as those located in a domestic context or more complex, such as commercial and other institutional spaces (Asensio, 2001; Honeyman, 2012).

Gruzman and Siqueira (2007) pointed out that currently the very conception of education is being extended towards the recognition of the importance of non-formal spaces in the promotion of cultural and scientific literacy of society. What we see in these spaces is a greater student involvement. In these environments the interaction with students is different, because there is not that sense of an obligation to learn what is on the blackboard or what the teacher is explaining and that may be on the test. Out of school the concern is to provide to the student a lifelong learning experience making him/her an active citizen, critical and curious, concerned about environmental causes and multipliers of sustainable actions at school, at home, on the street, in the neighborhood, etc. ...

The interactions that non-formal environments offer may, if well analyzed, contribute to science learning, helping to build more complex thinking processes (Jacobucci, 2008). According to Cazelli et al. (1997) interaction is not only manipulating modules, trigger buttons, light bulbs, having information, looking at models and panels, but also make associations and comments, react with verbal expressions or not, exchange impressions among peers and teachers. Being aware of the different forms of interaction resulting from verbal or non-verbal constructions that children manifest in these places is the opportunity of the teacher, clearly, to mediate the learning process by helping in the development of students' ability to organize, select, relate. These are skills needed to learn science.

2.3 Active Learning Strategies

The Active Learning pedagogical strategies are used in order to bring the student to discover a phenomenon and understand concepts for himself. And then, he is led to relate his findings with his prior knowledge of the world around him (McGrew et. al., 2000; Fink, 2003; Prince, 2004; Felder and Brent, 2009; Bonwell, 2011). Thus, it is expected that the knowledge built has more meaning than when information is transmitted to the student in a passive way. In Active Learning strategies, the students are the main agents of their knowledge building, acting to learn. According to McGrew and co-workers (2000), in this model, the instructor has the role of facilitator in the teaching-learning process and he has to act as a mediator aware of the process of knowledge construction of the students. The instructor must be the creator of tools and contextualized learning environments that are favorable to the independent, collaborative and transformative learning style. In other words, in this model the emphasis is placed on developing the students' conceptual, attitudinal and procedural skills and competences, providing a cognitive development at more advanced levels, such as analysis, synthesis and creation (Anderson et. al., 2001).

Many authors (Sridhar, 2005; Faland and Frenay, 2006; Graaff and Kolmos, 2007; Du et. Al., 2009) have proclaimed the Active Learning teaching strategies such as Problem Based Learning (PBL) and Project-based learning (POL or PjBL) as natural methodologies for engineering education, since these methodologies fit so well in the practice of engineering. By applying these strategies, of course, not intending to "fill" the head of the students with knowledge, but to provide them with a learning environment well suited to allow them to "learn to learn", and at the same time acquire a combination of knowledge, skills and attitudes needed to develop the professional skills necessary for an engineer.

In summary, one can say that the Active Learning strategies include a wide range of activities that share the common element of involving students in performing tasks and thinking critically and creatively about the tasks they perform (Bonwell and Eison, 1991), and therefore all these strategies can and should be used in all levels of education, preferably since early childhood education.

3 The Development of the Activity

From active learning strategies, the ENGFUT project developed the Scientific and Technological Rally, a competition divided into theoretical and practical tasks aimed at science and technology, as well as with cultural and recreational tasks, addressed to students of the two last years of high school. The RALLY goals are:

- To provide opportunities for high school students to develop a scientific vocation, through meaningful learning activities focused on science and technology;
- To instill in the participants the need to search and improvement of knowledge in the scientific field;
- To insert science education in the daily routine of the educational institutions, seeking a direct development of the subject at hand;
- Attracting students for the engineering programs, technology programs and science programs in general.

The Scientific and Technological Rally takes place during an entire day (usually on Saturday) and is divided into four steps:

Step 1 (Preparation of tasks): The tasks are developed by the engineering students from the University of Caxias do Sul, supervised by university teachers involved with the ENGFUT project. Tasks are on theoretical and practical issues involving subjects from the everyday matters of the engineers.

Step 2 (welcome reception): The teams are welcomed at the University de Caxias do Sul main campus (see Figures 1 and 2) and in next a lottery is performed to established the teams headquarters (HQs) (see Figures 3 and 4). The teams have as they first task to decorate their HQ with a theme inspired by the Rally.



Figure 1: Welcome Reception for the students at the University of Caxias do Sul



Figure 2: Welcome Reception for the students at the University of Caxias do Sul



Figure 3: Tiradentes High School HQ.



Figure 4: Alexandre Zattera High School HQ.

Step 3 (Performance of tasks): The tasks are announced sequentially (one after another) throughout the day. The tasks are oriented to engineering, science, and mathematics. For each task a time to delivery is set (see Figures 5, 6, 7 and 8).



Figure 5: Evaluation of the "Building a newspaper bridge" task



Figure 6: Running the "Archimedes Screw" task.



Figure 7: Parade of party clothes made of alternative materials.



Figure 8: Father Guerini High School finalizing its "Paper clips Eiffel Tower" task.

Step 4 (closing ceremony): Disclosure of the winning team and the delivery of the awards (see Figures 9 and 10).



Figure 9: São Rafael High School – second place in the 2013 Scientific and Technological Rally.



Figure 10: Caxias do Sul Technical School – first place in the 2013 Scientific and Technological Rally.

For the 2013 Scientific and Technological Rally, 20 schools from the region covered by the University of Caxias do Sul with a total of 200 high school students from the last two years of high school participated in the event. The winning team receives a notebook and a projector for their school and the students receive medals and trophies.

4 Final Remarks

This work aimed to present the Scientific and Technological Rally as a non-formal educational environment, an interactive and playful space that favors meaningful learning as defined by Ausubel (1982). Students may, in carrying out tasks, experience what was taught in their classrooms, perform different experiments, "walk" inside of science and technology, answer their questions, and be entrepreneurs in the achievement of the tasks.

We know that in many Brazilian schools there is a lack of physical structure and that even the simplest experiments are often not preformed. In this context, to promote a learning experience where the teacher's classroom can be supplemented with experiments is fascinating for the students and the teacher himself.

Additionally, we point out how the formal versus non-formal education relationship is established. In the Scientific and Technological Rally, students learn by experience and in a space outside of school, but there is intentionality. In the conception and preparation of the tasks, engineering students, monitors from the ENGFUT project, aimed at providing conditions for learning of natural and physical phenomena to occur by the high school

students. These engineering students have a different approach to the problems than the university instructors. In this context, they are people different from the usual figure of the high school teacher. Through specific language they build tasks to explain natural phenomena and technological problems.

The space offers the exchange of knowledge. Many students have experiences and also learning acquired through informal education, and while discussing with the monitors, previous doubts may be clarified. But we must point out that probably with formal education, held in the school, the students built a lot of their knowledge and which might be better understood when the theory/practice relationship was established as provided by the non-formal environment. So we must be clear that the non-formal education does not replace formal education. The non-formal education complements the formal mainly in these spaces that offer interactivity and participation.

The Scientific and Technological Rally encourages students to perform different tasks in the areas of science and technology therefore provides the student a multidisciplinary experience. The Rally leaves aside the fragmentation of knowledge taking the student to realize that the different areas are complementary and that needs each other to explain different phenomena.

One of the rally objectives is attracting young people for the engineering careers. Approximately, 550 students have participated in the ENGFUT activities since 2008. Data from the Directory of Academic Records of the University of Caxias do Sul show that 175 students of those 550 have enrolled in the University and, of these, 78 are of the science and technology majors.

Working in non-formal education environments opens a possibility to address and explore the contents worked out in the classroom in a contextualized and dynamic way, because in these environments interaction with students is differentiated. To develop activities that involve many participants and exploring the competition must always be well planned, seeking a methodology of easy understanding and development.

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The Synthesizer: a versatile active learning tool for electrical engineering

Martín Tarragona, Federico Davoine, Gabriel Eirea

Facultad de Ingeniería, Universidad de la República, Uruguay

Email: tarragona@fing.edu.uy, fdavoine@fing.edu.uy, geirea@fing.edu.uy

ABSTRACT

This paper presents a project-based course for Electrical Engineering (EE) freshman students, that is based on a modular analog synthesizer. The project topic creates high motivation and lends itself to basic EE concepts and skills, to which students are introduced gradually as they build the electronic modules collectively with the teachers' guidance. Once the basic modules are built and tested, interesting sound effects can be created while understanding the relationship between the different circuit parameters and the sound characteristics. This creates good conditions for an intuitive exploration of abstract concepts like time-domain, frequency-domain, frequency-spectrum, filtering, etc. Finally, students are presented with the challenge of creating a controller to play the synthesizer as a musical instrument. The results after our first experience are very positive, both in terms of students' motivation and achievement.

Keywords: interdisciplinary courses, tools for active learning, electronics and music

1 Introduction

A synthesizer is an electronic instrument that can generate a wide range of sounds, used extensively from the 60's to the 80's by artists from diverse musical styles. The synthesizer consists in several modular circuits (voltage-controlled oscillators, noise generators, voltage-controlled amplifiers, voltage-controlled filters, envelope generators, low-frequency oscillators, etc.) that can be creatively assembled and controlled in order to get different sound effects. Here, we present it as a versatile active learning tool for electrical engineering students, bridging music and electronics.

Teaching electronics for freshmen can be a daunting task. They arrive from high-school expecting to find in the university amazing technical projects related with electrical engineering. However, they can easily lose their enthusiasm if they start learning the complicated physics behind electronics components, such as diodes and transistors, or mathematical theory that will later be applied to circuit analysis.

In order to boost their motivation towards the career, hands-on methodologies are used in some universities, enabling students to work with digital circuits, robotics, etc. These projects usually involve high-level tasks, like micro-controllers programming or systems integration, but almost no low-level manipulation, given their complexity.

With the purpose of including low-level technical skills, we propose to use the synthesizer as the core of a hands-on subject on practical electronics for freshmen, based on open source resources (Bermúdez, 2013). Music synthesis is reported in the literature as a topic for introducing students to engineering concepts, but mostly digital (Douglas,

2001, Marpaung et al., 2011). We could only find one example of using analog synthesizers as a teaching tool (Billis et al., 2011).

2 Methodology

The course is organized as follows. First, students learn to recognize basic electronic components (resistors, capacitors, transistors, operational amplifiers), and are introduced to some basic blocks useful for an understanding of the principles of operation of different circuits (e.g., voltage-to-current converters, Schmitt triggers, etc.).

Next, students are divided in groups of six for the purpose of developing the projects. They are provided with handouts (see figure 1) containing the information needed to build each module: a brief description of the circuit function, schematics, PCB layout, bill of materials, and an overview of the circuit operation. In order to allow an active participation of every member in the construction of the modules, the groups of six are subdivided in groups of three. It was concluded that this was the optimal group size for learning the techniques and procedures involved in a practical implementation of an electronic circuit.

El VCO (Voltage Controlled Oscillator) junto con el Generador de Ruido son los módulos más importantes a la hora de generar señales de audio en la síntesis analógica. Su funcionalidad está dada por el hecho que a su salida se obtiene una señal cuya frecuencia fundamental está determinada por el voltaje de control dado a la entrada, como se verá más adelante. A continuación se presenta la información relevante para una implementación sencilla de un VCO..

Esquemático:

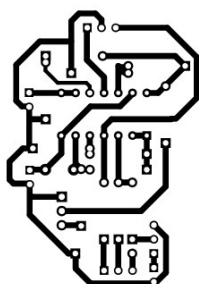
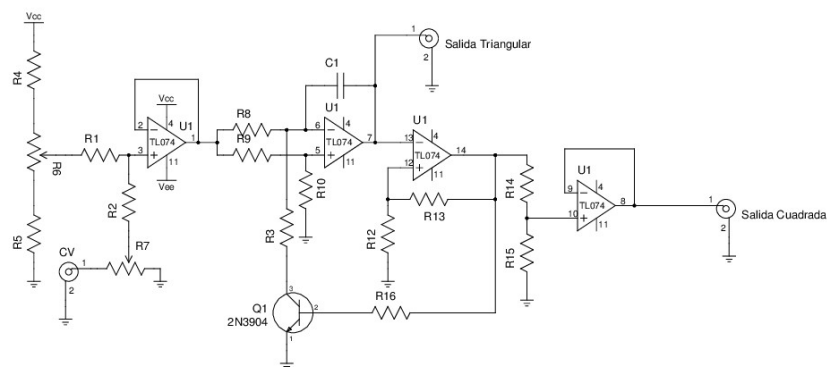


Figura 1: PCB

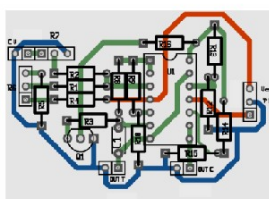


Figura 2: Layout

Lista de Componente	materiales: Valor
R4,R5	4,7K Ω
R14,R15,R16	10K Ω
R4,R9,R10	47K Ω
R1,R2,R8,R12,R13	100K Ω
R6,R7	200K Ω Lin
C1	10nF
Q1	2N3904
U1	TL074

Figure 1. First page of a handout example for the VCO module, with a brief introduction of the circuit, its schematics, PCB layout and bill of materials.

An outline of the process is described next. The layout of the PCB is transferred to a copper clad board (FR-2 or FR-4) manually with a permanent ink marker. The PCB is etched with ferric chloride under the supervision of the teachers; this process gives the opportunity to describe basic safety and environmental procedures. The etched board is drilled manually for thru-hole components. The final step is to populate and solder the discrete components onto the PCB; again, during the process the teachers describe the basic soldering techniques and safety procedures.

They start by assembling a voltage-control oscillator (VCO), that generates square and triangular waveforms whose frequency can be controlled by an external voltage input (control voltage, CV). Although the circuit is quite complex for the students, they are encouraged to understand it block by block, and using analogies with other physical systems. The circuit is tested by connecting it to an amplifier that feeds a speaker and looking at the waveforms

with an oscilloscope, allowing them to discuss and consolidate concepts that they learn at high-school, such as time and frequency.

Then, students assemble and test more modules: voltage-controlled amplifiers (VCA) and filters (VCF), noise (NG) and envelope generators (ADGen), etc., with increasing autonomy. Each device not only enhance the range of sound behaviours, but also serves as a base to work with some concepts, like noise, filtering, frequency spectrum, amplification, saturation, etc.

At the middle of the semester, each team presents to the class an example of operation of the whole synthesizer, generating and performing a sound effect by interconnecting the different modules in a creative way. They also have to present a written document, explaining how to use the modules built.

Some basic interconnections can be used as an example to foster the understanding of more abstract concepts. For example, Fig. 2 shows module configurations for vibrato and tremolo effects, which can be related to data transmission concepts like frequency modulation and amplitude modulation respectively. This creates an opportunity for teachers to introduce these and related concepts in an intuitive way, before they are presented formally to the students later in the curriculum.

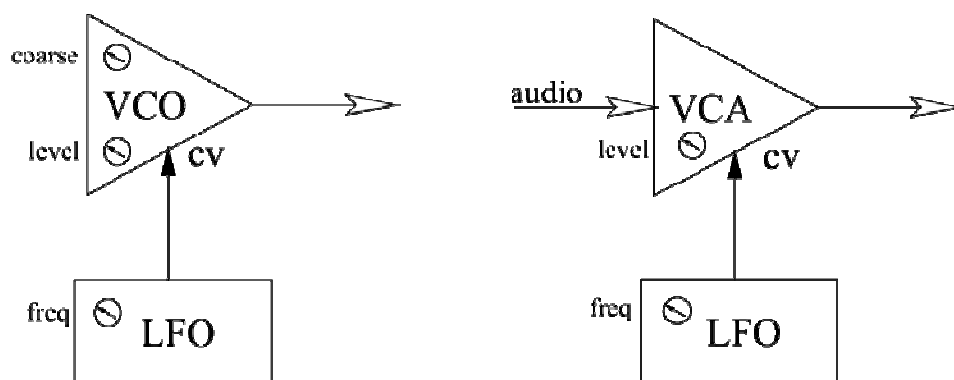


Figure 2. Basic interconnections of the synthesizer modules. Left: vibrato (frequency modulation), right: tremolo (amplitude modulation).

The second half of the semester is devoted to the development of a controller that will be used to play the synthesizer as a musical instrument. This is the most challenging part of the subject, because students have a large degree of autonomy to conceive and design their controller, with time as the only constraint. Although crazy ideas are accepted and even encouraged, it is important that students understand the role of the controller in the synthesizer, as a physical interface with the musician for manipulating the operation of the electronic modules with a musical intent, allowing a specific kind of artistic expression.

The students are presented with some transducers (e.g., phototransistors, light-dependent resistors, potentiometers, electret microphones, etc.) and basic blocks (e.g., triggers, impulse detectors, comparators, DC motors, etc.), and are also encouraged to discuss their own ideas with the teachers. The interaction of the group

members internally, with the teachers and with other groups, shapes the creative process that evolves with freedom but with technology constraints, until a definite idea is reached and implemented. The result is a device that allows a tangible interaction with the synthesizer modules, translating the musician stimulus into control voltages (CV).

Thanks to the collaboration of a teacher from the School of Music of the University, some groups are able to improve their designs, using inputs from another point of view. For example, a group had decided to work with light sensors that generate sounds, but not in an harmonic way. A more “musically acceptable” controller design would be too complex for them. However, after presenting their case to the music teacher, he showed them a non conventional form of music, based on a twelve-tone system, enabling them to understand their controller under new musical criteria.

The outcomes of each project are presented by them in the final session.

3 Results

Some of the controllers developed by the students are:

- ▣ laser harp: it is based on coupled pairs of lasers and phototransistors, being activated when a light beam is interrupted, generating a note according to the well-tempered scale (Fig. 3).

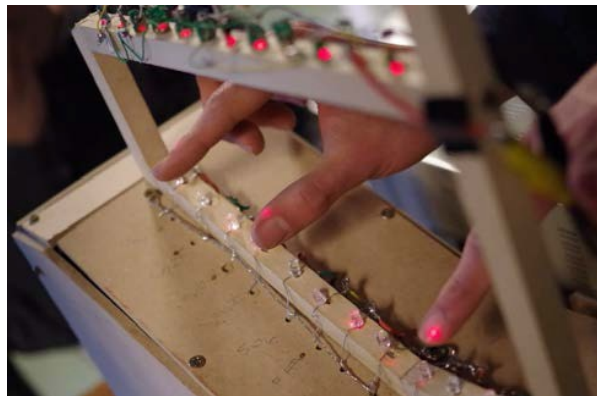


Figure 3. Laser harp

- ▣ ribbon: a steel string is placed above a resistive ribbon (extracted from a VHS tape), only being in contact when a player pushes the string and generates a control voltage (due to the voltage divider) for the VCO, as well as a trigger that activates an envelope for the VCA (Fig. 4).

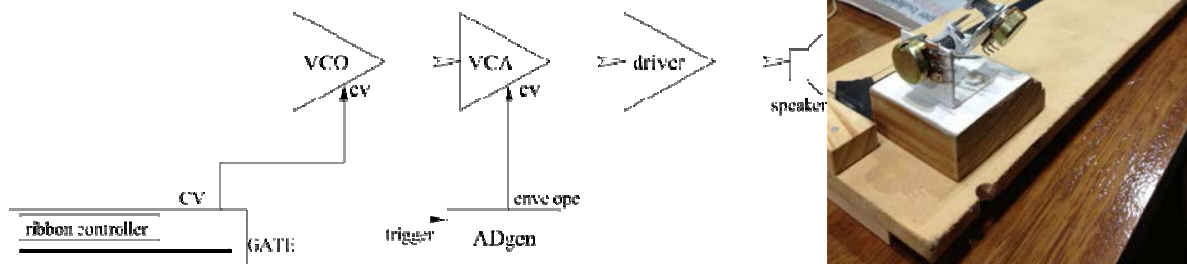


Figure 4. Ribbon controller. Left: block diagram. Right: photograph.

- carousel sequencer: the instrument uses an array of phototransistors equally distributed on a circumference, that are activated by three LEDs equally distributed on another rotating circumference driven by a DC motor; as the motor spins, the phototransistors are activated sequentially, generating different notes that are configured with a bank of switches. The rotation of the DC motor is controlled by an envelope generator triggered by a clap detector, thus creating a rich sound sequence every time hands are clapped (Fig. 5).

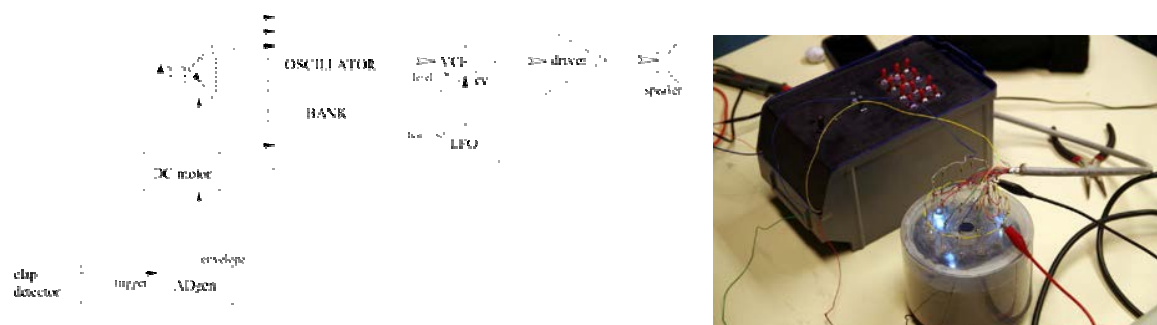


Figure 5. Carousel sequencer. Left: Block diagram, right: photograph.

- telephone keyboard: the classical keyboard controller is implemented with a twist, since a recycled telephone keyboard takes the place of traditional black and white keys; the resulting instrument resembles somehow a bandoneon because of the peculiar key arrangement.

- ② guitar-shaped signal router: pairs of lasers and phototransistors mounted on a guitar-shaped board are used to route the synthesizer's signals, so different module interconnections and parameters can be selected with the fingers, generating a changing combination of sounds.

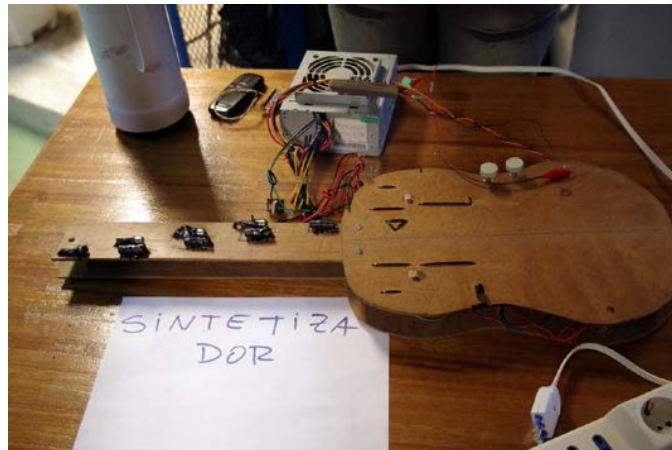


Figure 6. Guitar-shaped signal router.

- ② coupled sequencers: this project uses two coupled sequencers, each generating an independent set of CVs that are added to create the CV for the VCO; since one of the sequencers' tempo is a fraction of the other's, interesting transposed arpeggio sequences are generated.

4 Conclusions

The main advantages of using the synthesizer within the electrical engineering curriculum are:

- ② Modularity: students can build, understand and test it by stages; they can build only the basic modules (VCO, VCA, VCF, NG and ADGen) or add more to enhance the range of possible sounds. More advanced students can even design new and more complex modules.
- ② Low barriers to entry: the skills and tools needed for building and testing each module are very basic and don't require previous experience.
- ② High ceiling: while it is possible to create an interesting musical instrument with basic skills, there are endless opportunities to improve the design with more complex modules that require advanced electronics concepts, and so students can continue the development in later stages of their studies.
- ② Low cost: only standard electronics components and tools are needed. A special workspace is not required: students can even work in their own homes.
- ② High satisfaction: the synthesizer is a real musical instrument that can be played by controlling electrical signals, enabling students to link electronic operation with sounds; they can also demonstrate it to non-technical public, such as their friends and families, boosting their motivation.
- ② Direct links with other subjects: from the first class, students learn to manipulate and understand electronic components that they study theoretically in physics subjects; besides that, they can link musical concepts such as tremolo and vibrato with their corresponding signal modulations (amplitude and frequency), widely used in engineering applications.

- ② Interdisciplinary: music students can also participate of synthesizer workshops, learning from engineering students how it works and providing new ideas on how to assemble and play it; conversely, engineering students can learn from their music counterparts.



Figure 7. Workshop with a music teacher.

According to our experience, the synthesizer can be used as an active learning tool for a wide range of electrical engineering students. Freshmen learn practical electronics by building the basic modules and controllers, whereas more advanced students can develop complex modules for special musical effects. In all the cases, students also develop design and project management skills, by going from the idea of new controllers and modules to their design and testing.



Figure 8. Students after the final session.

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Developing electronic devices for the disabled as an active learning experience in Electrical Engineering

Gabriel Eirea, Federico Davoine

Facultad de Ingeniería, Universidad de la República, Uruguay

Email: geirea@fing.edu.uy, fdavoine@fing.edu.uy

Abstract

This paper presents an optional course for Electrical Engineering students of all levels that focuses on the development of electronic devices for the disabled. The objective of the course is to give students a practical hands-on experience in basic electronics as well as to create an open-source library of designs that can be easily replicated and provide affordable devices for people with disabilities. Results show a high motivation for the students, that embrace the active learning experience as an opportunity to learn practical electronics skills and contribute to the welfare of a vulnerable population, reflecting on the social role of technology.

Keywords - disabilities, electronic devices, active learning

1 Introduction

It is generally accepted that project-based learning is a highly effective approach to teaching engineering (Mills & Treagust, 2003) (Savery & Duffy, 1995). More recently the introduction of design thinking concepts in the engineering curriculum was proposed (Dym et al., 2005).

On the other hand, service learning is acknowledged as a positive approach for teaching problem solving skills and improving students' motivation, while at the same time engaging the community and developing citizenship among the students (Bringle & Hatcher, 1996).

The course presented here is inspired by these trends and follows similar motivations and methodology as the ones described by Bykbaev et al. (2011) for senior Engineering students and Godino-Llorente et al. (2012) for EE Masters' students.

The main idea behind this course is to provide a highly motivating experience for engineering students with the combination of a project-based approach to learning basic electronics, with a meaningful project that can have positive impact in real life.

According to official sources from 2004 (INE, 2004), 7.6% of Uruguayan population has at least one disability, totalling 210,000 persons and affecting 21% of homes. The disabilities are distributed as motor difficulties (31%), vision impairment (25%), audition impairment (14%), mental disabilities related to learning (12%), mental disabilities related to socialization (7%), and others.

One particular characteristic of electronic devices for the disabled is that a wide range of useful devices is of low technological complexity, however the market dynamics are such that commercially available products are expensive and out of reach for most of the population. In a small country as ours, many devices are not even available locally and have to be imported by individuals or institutions, increasing the total cost. In this context, the

challenge to develop solutions that can be replicated locally and distributed at a low cost to people with disabilities provides a strong motivation for students. Besides learning to create and build basic electronics projects, the students have the opportunity to have a positive impact in a vulnerable population.

2 Methodology

The course consists of three distinct phases. The first one is composed by two lectures about disability given by specialists in the subject, with the goal of providing a context for the course. The topics are: characterization of disabled people in Uruguay, institutional context, technology applied to disabilities, the concept of digital ramps. Many examples of existing commercial devices are presented, evaluating their strong and weak points, and showing their practical use in disabled people's day-to-day life.

Next, the students are presented with three lab sessions about practical electronics. These hands-on sessions introduce basic abilities like identification of electronic components, use of basic instruments, Arduino programming (Arduino, 2013), creating printed circuit boards (PCB) and soldering techniques.

After these two phases, the students have introductory notions in the two main topics involved in this course. They will continue to develop their knowledge about electronics and the technological needs of disabled people in an autonomous way, within their final projects.

The students are divided in groups of three and each group works in a project with the help of the teachers. Teams can choose between projects based on specifications drawn by NGO experts or to join an educational project in schools for disabled people.

In the first case, students have to develop projects that meet specifications supplied by experts from the health area, without any direct contact with the final users. Each group is given enough room in the technical definition to develop their creativity, with time and money constraints. In general, students use electronic components available in the country.

The role of the teachers is to help students with their technical doubts, teaching them extra tools if needed, such as software for designing electronic layouts. The students organize their work by themselves, working at the University or at their own homes.

The projects are characterized for being of relatively low technical complexity so they can be approached successfully by students without previous experience. However, this does not mean that the resulting products are of little use, since these devices are generally out of reach of the general population due to the nonexistence of a local market for them and a high cost of import. The students are asked to write a step-by-step guide for constructing the devices, that is published in the course website (Taller de Electrónica Libre, 2013) and becomes available to anyone who wants to replicate them.

On the other hand, students who choose the second path are incorporated to a multidisciplinary team (Flor de Ceibo, 2013) that works promoting Information and Communication Technologies within the framework of Ceibal Plan, that is a One Laptop per Child implementation in Uruguay (Plan Ceibal, 2013). They make visits to the primary schools for disabled people, where they meet children with cerebral palsy needing technological ramps. Their interaction with the teachers and the multidisciplinary team (composed of several students from the University and led by a teacher from Psychology) helps them to understand the raw reality that they find in the schools. In order to do that, they take part of some meeting of the whole team and of some activities with the disabled children (DanceAbility, 2013).

These students develop low-cost switches made with everyday materials and adapted for specific children, given they have different levels of motor control in different body parts (hands, feet, head). They also offer workshops for teachers and relatives of disabled children on how to build the devices, teaching them basic concepts of circuits and electronics.

At the end of the course, students make a public presentation of their projects, not only showing their results but also the process that they undertook. This is an opportunity to exercise oral communication abilities, in many cases

being the first time students face this challenge at the university level. The presentation is open to the general public, with special invitations to the different organizations that worked in collaboration during the semester.

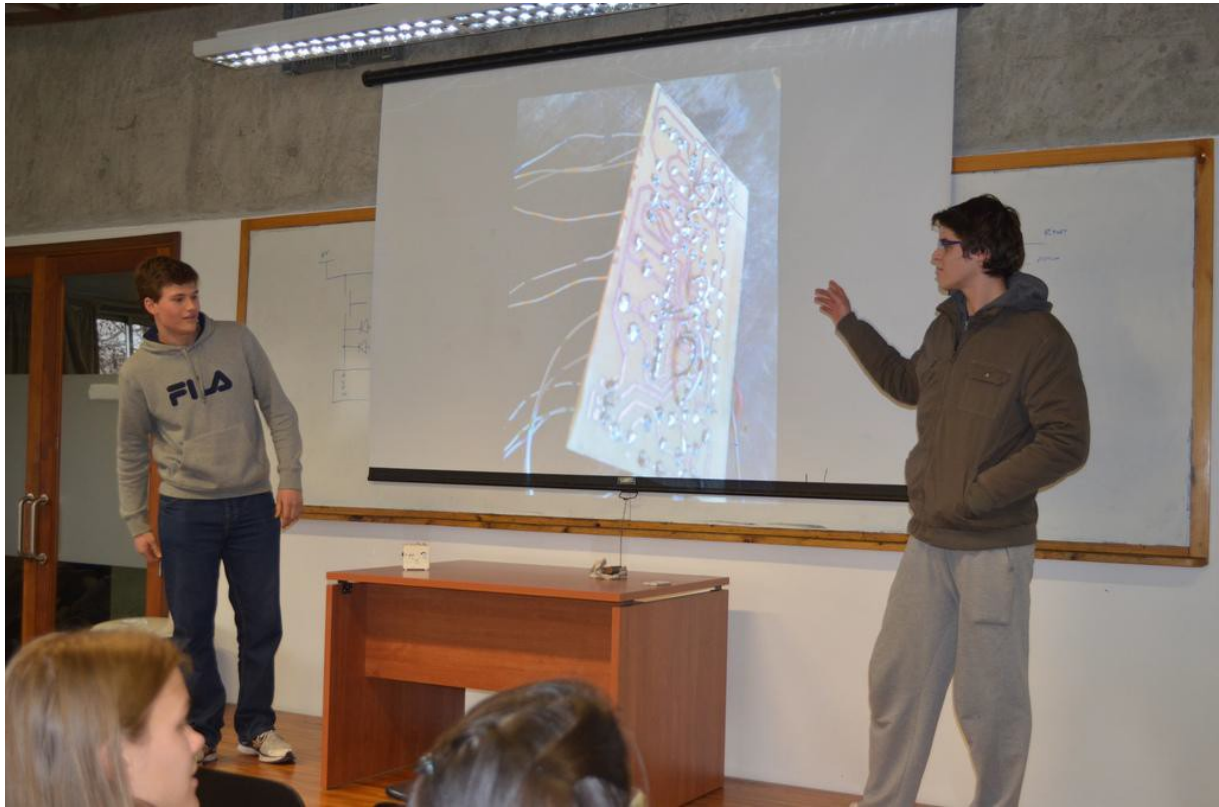


Figure 1. Students presenting their projects at the end of the course

3 Results

Some of the devices developed by the students are:

- ▣ low-cost switches: after analyzing different alternatives, the students arrived at a novel design implemented with cheap and easily available materials like plastic sheets, screws, washers, weather strips, recycled headphone cables, etc. (Fig. 2).

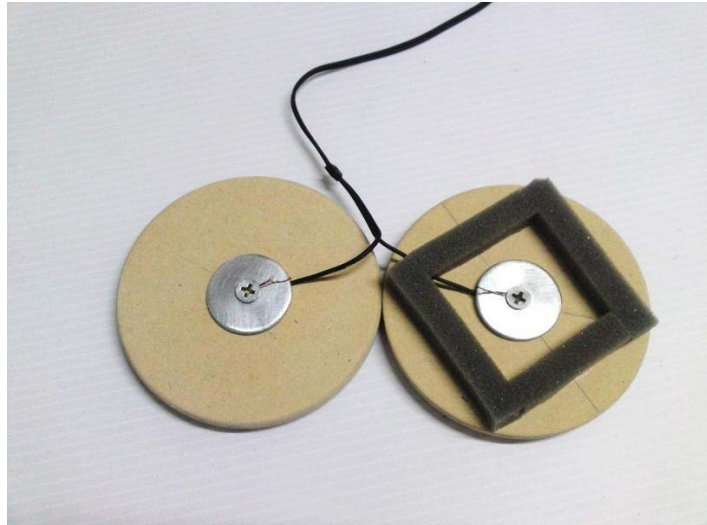


Figure 2. Low-cost switch construction.

- ❑ mouse adaptations for external switches: this classic adaptation introduces a jack mounted on the mouse chassis that is connected in parallel with the left-click switch.
- ❑ keyboard adaptations for emulating the mouse movement: this adaptation required opening and reverse-engineering an existing computer keyboard, routing the connections corresponding to the arrow and enter keys to large buttons built on top of a cabinet; with an adequate configuration in the Operating System, the arrow keys can be used to move the mouse pointer in the screen, while the enter key acts as the left-click switch.
- ❑ picture-based communicators with scanning: this design implements a sequential activation of LEDs with stop and reset buttons that can be activated with external switches.
- ❑ blackboard-based communicator with wireless controls: this project uses a scanning method similar to the previous one, but the activation signals are taken from four wireless devices and the area for placing pictures is larger, so it can be used at a larger distance by many students at once.
- ❑ voice-based communicators: two different designs for communicators were implemented using commercial voice-recording chips, one for a single message, and the other for multiple messages; the communicators can be activated by mounted as well as external switches.
- ❑ toy adaptations for external switches: several toys with simple electronic functions were adapted for activation with external switches, in every case a special analysis of the internal circuit was performed and

wires connecting to a jack were introduced in the convenient place; some of the toys adapted are remote-controlled cars and stuffed toys with sound, lights and/or movable parts.

- ▣ induction loops for hearing aids: this project consists of building and testing induction loop amplifiers, based on schematics provided by the teachers.

There were two workshops implemented: one with teachers and the other with relatives of children with disabilities (Fig. 3). These hands-on workshops were focused on the building of switches and toy adaptations. The students prepared and directed the workshops, being able to communicate with non-technical persons the basic elements and methods for building the devices. Many switches were built and several toy adaptations were successfully implemented during the workshops, empowering the attendants to replicate the work in the future to cover for their needs.



Figure 3. Primary school teachers assembling low-tech devices for disabled children from their school.

4 Case study

Children with cerebral palsy may experience several communication impairments, due to difficulties in their motor control as well as in their cognitive development. In particular, they cannot produce speech appropriately due to motor disorders and their language development can be delayed (Pennington, 2008). Some studies report that between 16% and 24% of children with cerebral palsy cannot communicate verbally, needing some kind of

augmentative and alternative communication (AAC) system (Clark, 2012), in order to communicate their decisions in another way.

One widely used AAC system is called switch access scanning and consists in a board with several messages (for example: "I want to play", "I want to go to the bathroom", "I love you", etc) displayed graphically and sometimes accompanied by short words in big size (some children have sight difficulties too). The most basic low-tech device is simply a board with several printed cards with messages, that are pointed sequentially by another person who wants to know what the child is trying to communicate, until the child makes some kind of signal (movement or sound). However, this kind of device requires that the adult has to be in front of the child exactly when the child takes a decision, probably for a long time, because it may be difficult to get them concentrated.

On the other hand, there are software implementations of the switch access scanning system, based even in the Sugar environment installed in the XO laptops of the Ceibal Plan. Though the software does not need adult supervision, few children use it intensively, given that they can almost no manage the small dimensions of the XO laptop. Standard PC or laptops can be used, but the first ones are very cumbersome and the second ones can be easily broken by sudden involuntary movements.

Therefore, in the context of the course, some students developed prototypes of electronic versions of this AAC technique, combining the advantages of both low-tech and software implementations. One project was a picture-based communicators with scanning, based on a simple circuit composed by a counter, a timer and digital gates, that sequentially turn on LEDs placed on a plastic box, each one associated to a card with a message (see Fig. 4, left). The child can stop the sequence using a custom-made push-button connected to the box. The last LED selected remains on until an adult comes to see the message left by the child. The time interval between LEDs can be adjusted by an adult, given that some children with cognitive difficulties may need more time than others to decide whether to select or not the current option.

Another project, the blackboard-based communicator, was based on the same principle, but for a different context: a classroom. Primary school teachers make use of the scanning system for the whole class, with a low-tech board next to the standard chalk blackboard. A team of students built a full-size version of it (design shown in Fig. 4, right), using similar technology to that of the previous project, with the addition of wireless doorbell devices to make remote controls for the children. When one child sees the option that he wants to communicate, she pushes a button connected to her remote control, stopping the scanning sequence. There is also another set of LEDs that identify the remote control used to stop the scan. Then, the teacher can know at the same time who pushed which option, and work with that. The teacher has the possibility of restarting the device to allow the other children to say what they want, or to work with a different question.

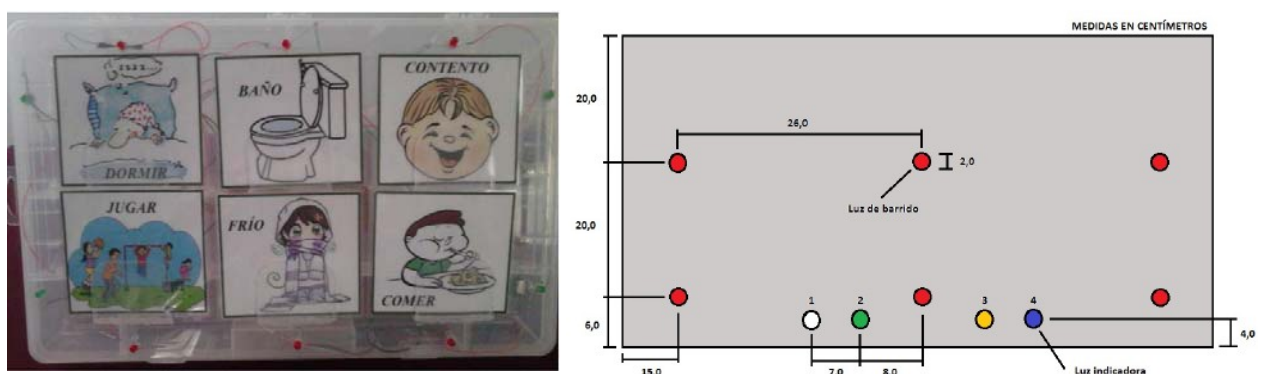


Figure 4. Individual switch access scanning device (left) with message cards and its corresponding LEDs. The device shown on the right is for use in the classroom: 6 red LEDs (indicated by circles) correspond to different options, whereas the 4 LEDs with different colours are assigned to the remote controls used by the children (via push-buttons).

5 Conclusions

The results show that students have a high motivation both for having the opportunity to work in a practical project and for contributing to the welfare of a vulnerable population. This was evidenced by students' performance and commitment during the whole semester, in some cases going beyond the end of the semester.

The simplicity of the electronic designs and the generation of documentation with blueprints and instructions available freely online, enables any person with basic knowledge in electronics to replicate these devices, increasing the impact of the students' work.

This course was able to fill the gap between the academic teaching of technical subjects and the social role of technology. Not only did the course introduce students to practical electronics, problem-solving and team-working skills, but also by engaging the community, the course promoted the personal development of the students.

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Workspaces for active learning: chemistry workshop to students

Ana Maria Coulon Grisa, Rosmary Nichele Brandalise, William Ribeiro

Center for Science and Technology, University of Caxias do Sul, Caxias do Sul, RS, Brazil

Email: amcgrisa@ucs.br , rnbranda@terra.com.br,wribeiro@ucs.br

ABSTRACT

This paper presents the activities promoted in the Chemistry workshop, which composed the Project PetroFut / UCS-Promopetro: New Challenges for the Future Engineer developed at the University of Caxias do Sul (UCS). This study promotes the interaction of the engineering sciences with high school students regarding the chemistry workshop. The workshop provided to high school students the applicability in engineering, with interdisciplinary concepts of the disciplines: chemistry, physics and mathematics. The main purpose is to arouse the interest of students to attend engineering through active, interdisciplinary and significant learning. In Brazil 45 billion Engineers graduate per year , while the need would be 70 thousand. It is estimated that the development of a country is closely linked to professionals of technological areas. Looking for arousing the interest of students for the technological areas, this paper proposed building dynamic activities and with the active participation of all involved. This article presents the results of the workshop based on active learning, learning problems in the Laboratory of Polymers. During implementation the integration of students was promoted and also an approach of high school students with the university. 60% of the students who participated in the workshop commented that it was more interesting and productive learning chemistry, physics and mathematics through this activity. They will be accompanied by a group of professors in this workshop for the next two years related to their performance in the entrance examination for Engineering at UCS and once inside graduation, in the basic subjects - math, chemistry and physics.

1 Introduction

The learning process using recognition, analysis and problem solving is a trend that has been growing in the educational system (KISCHNER, 2002). The engineer today is no longer the one who only applies in a technical way the knowledge of these days, he must participate actively and effectively in all stages. He has tasks that require interaction with other areas of the production system, analysis of the social and technological innovations (IEL, 2006). As a way to implement these guidelines into practice for the chemistry teachers when working with themes and contextualized situations or problems, it can be seen the opportunity to create new situations, aimed at the development of an independent student, active subject of their own learning, besides being a path that can lead to improvements in teaching and learning (ARROIO *et al.*, 2005). Meaningful learning requires that the material to be learned is potentially meaningful to the learner. The more is the interdisciplinary teaching, and challenging are the education proposals, the greater the possibility of capturing the world by the people who learn (Pombo, 2003). Learning tasks with significant focus, as the usage of everyday materials, experiments, and problem solving experiences, allows the approach of the object of study enabling concept formation that always arises in the process of solving a problem (Vygotsky, 2000). Modern society is increasingly dependent on petroleum products, the polymeric materials. The synthetic polymers derived from petrochemical become an environmental problem if discarded inappropriately (MANZUR, 2009). In order to minimize the impact of the polymers usage, and consequently the generation of waste, practical activities should be offered to students at all levels of education. Providing environments where they can build knowledge about the recovery and recycling of waste from the practice of significant experiences, and giving meaning to these concepts in basic training subjects as chemistry, physics and mathematics have been one of the strategies used to bring students to engineering courses. In this paper the authors, in the workshop high school students participated in practical activities using the infrastructure from the University, interacting with graduates and professors and also developing activities that allowed to interact with current issues, together with some school subjects. Therefore arousing the interest of students for the technological areas

2 Learning with workshop

Current trends in education point to the use of active methods of teaching and learning, aimed at making the student the protagonist of his own knowledge acquiring process (fonte!!). The methodologies are based on active learning strategies that allow reading and intervention on reality, favoring the interaction between teachers and the collective construction of knowledge. The problem-based education works to build knowledge from significant experiences (Freire, 2010).

According to Sá & Silva (2008), an interdisciplinary chemistry teaching is a promoter of an active and meaningful learning. The National Curriculum for High School - PCNEM (Brazil, 1999) suggests the use of social issues to establish chemistry interrelationships with the various fields of science, allowing an overview of scientific knowledge, which is essential for the construction of citizenship, interpretation of the physical world and understanding of the transformations that occur in it.

According to Powell & Weenk (2003), the main competencies to be developed in engineering education are knowledge, skills and attitudes, active learning projects itself as a viable alternative to education. Putting together the basis of theory - practice of teaching with the teaching-learning process requires the understanding that "learning is not just passive reproduction but active acquisition involving creation and invention" (Dongo-Montoya, 2009). In active learning is worth noting that "learning is a process through which knowledge is constructed in an active manner, which represents the other end to receive knowledge passively through instruction". The educational process consists of a set of teaching and learning processes and materials with the goals of acquiring some knowledge.

During the experimental activities proposed most students felt difficulties in organization and orientation in the task, as well as they did not internalized "experimentally" the associated mechanisms related to this type of activity. It is essential to have the direct involvement of students in their own learning, performing hands-on activities that are based on "learning to do".

According to Schiel (2005), the consequences of Active Pedagogics have as center line to make students participate in the discovery of the phenomena studied, putting them in contact with objects of observation and experimentation, stimulating the imagination and creation. This way of working with students, especially in groups, can promote greater opportunities for expansion of scientific knowledge, and provide another opportunity to understand the intricacies of scientific activity (problem to be solved, lifting hypothesis, testing, redesign of problems etc. Capecchi and Carvalho (2000), argue that it is essential, during classes, the argument between the students, because through it they develop important skills such as recognition between contradictory statements, identifying and collating evidence theories.

Schiel (2005), said that in development with hands-on activities, sets of activities are planned, divided into classes, to develop different Science themes. "All knowledge is an answer to a question," the program's methodology, at first, the questioning proposed by the teacher, that is accompanied by a step of lifting hypotheses and then by conducting an experiment. Generally, such activities are carried out in groups, in order to stimulate discussion among peers and enhancement of spontaneous concepts. At the end, students express their results through oral presentations and written essays.

Creating environments through workshops that provide students to deal with problems, case studies, challenges, interventions in real situations, constructing arguments and possibilities for joint actions, seems to be an alternative to arouse the interest of students to attend Engineering. The workshop activities were based on already known content by the students of high school aiming to promote active learning, establishing meaningful relationships in Chemistry, with Mathematics and Physics.

2.1 The Chemistry Workshop

The activities were conducted with 27 students from state and municipal schools in the region of Caxias do Sul, Rio Grande do Sul, Brasil in order to arouse interest in high school students by science, research and technology areas that aim sustainable development. With the implementation of interdisciplinary teaching proposal it started with the rescue of the students' previous knowledge about the subjects: polymers and recycling.

Seeking to arouse the interest in elementary students for courses in the technological area, a workshop with practical activities were proposed offering challenges to solving problems related to polymer waste, environment, recycling and problem solving techniques.

The workshop aimed to apply the strategy *hands-on* that besides arousing greater interest and motivate students, also provides a better understanding of the theoretical content, thus favoring the assimilation of several important concepts. It is important to enable the student to observe, manipulate, reflect, discuss with a group and record their ideas and thoughts of what is observed (Shiel, 2005).

In seeking to explain the phenomena of everyday life of the learner, and insert it in the learning process, it is necessary to give meaning to concepts. The contextualization must first assume that all knowledge undergoes an interaction between subject and object. Thus, the learner can demonstrate knowledge, establishing relationships with its day by day.

The proposed study was initially supported in the method learning by questioning, on polymers day by day, polymeric waste and recycling.

At the beginning of the workshop, through visual aid, a presentation was done to show the production of polymers from the fractional distillation of oil. A concept was constructed of macromolecule polymer, the chemistry reaction that leads to polymer formation, polymerization, and the ratio between the chemical structure and the properties especially for polymers in this study: polypropylene and silicone.

The cups of coffee and water, made of polypropylene collected at University of Caxias do Sul, in specific plastic containers, were used by students in an activity that included the experiences of all the steps that comprise the process of mechanical recycling of plastics. The recycling comprising the steps of: washing the polymeric material, milling, drying, injection and compression molding of polymeric residues.

Students in the Laboratory of Polymer-UCS, made contact with some transformation processes of polymeric materials such as extrusion and injection. Essential equipments for transforming raw materials into polymeric artifacts.

Students observed the production of an artifact dispensers by injection process while receiving information regarding the injection equipment, also the usage it in the production of polymeric artifacts and on the labor market in the materials area.

With the polymeric residue of plastic cups made of PP and collected at University of Caxias do Sul, students were challenged to develop a hands-on activity according to the steps described below. In the proposed activities, students applied knowledge learned in mathematics, physics and chemistry. The challenge was to determine the mass amount in silicone needed to completely fill a ball specimen and use the residue of PP mixed with silicone to assess.

(a) Then it was offered to students a ping pong ball and a small cup of coffee. From the presentation of these materials, the groups were encouraged to describe constitution, properties such as density, mass, and volume of materials to determine.

(b) To each group of students it was provided string, scissors, ruler, paper, pencil, calculator and high school books of Mathematics, Physics and Chemistry. The proposed activity hands-on for the group was to determine the volume of the ping pong ball (Fig. 1) in order to predict the amount of mass needed to fill this volume.

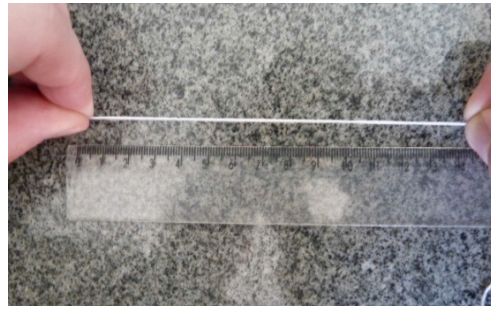
(c) Later, students filled the ping pong ball with the mass determined. After there was a debate on the recycling of polymeric materials related to the cup made of PP. Later groups were challenged in preparing a silicone ball with the addition of the PP waste.

(d) Silicone rubber was prepared by mixing 40g of silicone rubber and 40 drops of catalyst and drops of food coloring to color the ball. After mixing, the material was poured into the mold (Fig. 2) curing for 24 hours at temperature environment. After the removal of the outer plastic tack of the ping pong ball which was the specimen it became a white silicone ball and a pink silicone ball + PP residue 0,5g.

(e) Wait for the curing of the silicone in the molds with subsequent removal of the mold.



(a)



(b)

Fig 1 – Determination of the diameter measurement to determine the volume of the ping pong ball



(a)



(b)



(c)



(d)



(e)



(f)

Figure 2 - Preparation steps. (A) mold, (b) commercial silicone for the mixture, (c) mixing, (d) disposal in the mold, (e) view of the material in the mold (silicone ball + PP residue within mold in the curing process) and (f) silicone balls

At the second meeting the students having the silicone balls with and without PP waste, determined the mass, volume and density of the samples (Fig. 3).



(a)



(b)



(c)



(d)

Fig 3.- Procedure for determining the density silicone balls with and without PP waste.

The groups were challenged to determine the free fall time of each sample and the influence of the addition of polymer waste on the properties (Fig. 4)



Fig 4 - Determination the free fall time of the ping pong ball.

With of the books of Mathematics and Physics students in group condutec research into the formulas and units for determining the density and velocity of the samples free fall. To calculate density students used the Equations 1, 2 e 3.

$$V = 4\pi r^3 / 3 \quad (1)$$

$$s = gt^2/2 \text{ e } v = gt \quad (2)$$

$$d = m/V \quad (3)$$

Being volume in cm^3 , free fall in m, time in s, and density in $\text{g} \cdot \text{cm}^{-3}$.

The concepts of Math, Physics and Chemistry were applied to solve the challenges proposed and they were monitored by the data obtained in the construction of critical knowledge and understanding of physical density and the fall of samples with different chemical compositions also learning the math of these concepts.

3 Results

Table x shows the result of measuring mass and volume of the liquid displaced in each experiment, the density and the freefall speed of the white silicone ball and the colored ball made with silicone + PP residue.

Tab 1 - Results of the measured mass and volume, the density and freefall speed of the white silicone ball and silicone colored ball + PP residue.

	White ball (silicone)	Colored ball (silicone + PP residue)
Mass (g)	41,4	55
Ball Volume (cm^3)	45	47
Volume de água deslocada (cm^3)	23	25
Density (g/cm^3)	1,8	2,2
Freefall speed (m/s)	0,19	0,27

4 CONCLUSION

Seeing the results obtained using PP as residue, which increased the density of silicon ball + PP residue, students was asked to evaluate whether the values for volume of displaced water and drop rate had free consistency.

A long debate started and it was asked that the discussion should be based in the concepts of physics and mathematics and other examples were applied to reason the different opinions. At the end of the workshop the students realized that they used physics and mathematics as a tool to support their reasoning in relation to solving a problem that was proposed. They practiced the critical sense interacted with different groups, proposed other ways to confirm the hypotheses formulated and they concluded that it is important to use waste by recycling processes and finally enjoyed the proposed activity.

The quality of any activity performed depends on several factors such as prior knowledge the student has and how to use it also knowledge already constructed, and the way of living the new challenges.

The activities developed were processed in an active and meaningful learning process, enabling students to select and organize information establishing relationships. It is noted that teaching does not take place in isolation and that it is required to have an integration of different concepts in a dynamic way with examples of living in the environment where the student is inserted. So learning occurs more significantly to the student, allowing him to seek solutions for the problem situations they will face.

Active learning and the interrelationship between different areas of knowledge, social, technological and environmental aspects aim to highlight the importance of the areas and awaken young people's interest in scientific and technological knowledge that are relevant to demystify the vision of professors over the Engineering course.

Students need to be encouraged to learn how to learn and several actions can arouse in the pupil the taste for Engineering and the various disciplines help describe the world around them, to understand and unravel existing technologies that serve as the basis for applications in resolutions and problem situations of their everyday life.

27 students attended the workshop and 60% commented that it was more interesting and productive to learn chemistry, physics and mathematics by this activity. And of these 27, 60% said they had interest in attending an engineering course in the future. These students will be accompanied by a group of professors in this workshop, for the next two years, in relation to their performance in the entrance examination for Engineering at UCS and once inside graduation in the basic disciplines - mathematics, chemistry and physics.

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Inatel Maps: a project based learning approach for the algorithms class

Lúcio Henrique de Oliveira & Carlos Alberto Ynoguti

Instituto Nacional de Telecomunicações, Santa Rita do Sapucaí, Brazil

Email: lucio.henrique@inatel.br, ynoguti@inatel.br

Abstract

Maps are fascinating for most people: almost everybody have tried to locate their home city or a far away country in a map or in a globe. Nowadays, GPS equipments, Google Maps and Google Earth, among others, make the "maps experience" more attractive: it is possible to trace a route from a city to another, with instructions and very precise time estimates, to verify where the nearest supermarket is, and even to see the real appearance of a given building. This scenario was used to introduce some concepts of the Algorithms III class for sophomore students of Computer Engineering course. The project goal is to develop a software that is able to determine the shortest path between two points in a map. This scenario addresses specifically the graphs, sorting and searching topics, although the complexity analysis and algorithms design techniques can be cited as being beneficiaries of this project. In this paper, the adopted methodology, together with some preliminary results are reported.

Keywords: algorithms learning, project based learning, group working.

1 Introduction

Some studies have been conducted in Brazil to analyse the dropout rate of engineering students, comparing it to other countries (Testezlaf, 2010) (Silva Filho et al, 2007): the conclusions of this work are that the Brazilian situation is approximately the same as of other countries.

The main reasons for student dropout in engineering courses include: the failure in courses, the excessive amount of basic subjects (math, physics, and others) and the lack of "engineering things" in the initial years (Silva et al, 2006). This mismatch between the expectations of students and the scenario encountered when joining an engineering college assumes greater proportions for today's youth, known as "Generation Y" or "Millennials", whose main characteristics are its immediacy, superficiality, the informality, the intense use of technology, be ambiguous and transient in their choices and the ability to do several things at once (Oliveira, 2010).

To address these issues, some initiatives were proposed in the literature to make engineering courses more attractive for Millennial students (Mota et al, 2004), (Brereton, 2011) and (Mello, 2003). Most of them make use of real life projects, group work, constant feedback, among others, as ingredients to achieve success in the learning process. The present work focuses this problem: how to make engineering courses more attractive for the students.

1.1 Motivation

Algorithms are one of the basis of Computer Science, so mastering this subject is very important for all professionals working in this area. On the other hand, textbooks usually try to convey information as clear as possible, and the available exercises are designed to maximize the understanding of a given topic. For example, in a chapter that deals with graph theory, the exercises are all about graphs: there is no room for other kind of exercise, since the chapter is about graphs. And this is the way most of professors teach these (and other) subjects.

The problem is that this approach has little to do with the "engineering things" that the students are waiting for. This is a paradox: most of the results in algorithms theory (and science in general) were motivated by real world problems, and we use to teach these concepts in a way that is totally divorced from the real world.

Should we trash our textbooks and start from scratch? We don't think so. One alternative would be to use the textbooks as information sources, but to not be restricted to them in classes. Classes could be used to meet the students demands for specific topics that are needed to solve a given problem. If the problem is properly chosen, then it would be possible to cover the contents in a more applied way. Also, real world problems are in general

multidisciplinary, open ended and much more complex than the problems present in textbooks. Finally, this approach could be more interesting for the students than traditional textbook problems.

This paper proposes a project based approach for algorithm teaching for sophomore Computer Engineering students, where the students have to develop a piece of software that is able to calculate the best path between 2 cities in a map.

2 Methodology

Maps are fascinating for most people: almost everybody have tried to locate their home city or a far away country in a map or in a globe. Nowadays, GPS equipments, Google Maps and Google Earth, among others, make the "maps experience" more attractive: it is possible to trace a route from a city to another, with instructions and very precise time estimates, to verify where the nearest supermarket is, and even to see the real appearance of a given building.

This scenario was used to introduce some concepts of the Algorithms III class for sophomore students of Computer Engineering course.

2.1 Course organization

The topics covered in this course are: complexity analysis, sorting and searching algorithms, algorithm design techniques, graphs, geometric algorithms and string manipulating algorithms.

This course is divided into theoretical and practical classes, with 1:30 hours weekly meetings each. The theoretical part is conducted in the tradition way, with lectures, exercises and tests, by a professor. The students work in the projects during the practical classes, oriented by a TA (Teacher Assistant).

2.2 Project description

The project goal is to develop a software that is able to determine the shortest path between two points in a map. This scenario addresses specifically the graphs, sorting and searching topics, although the complexity analysis and algorithm design techniques can be cited as being beneficiaries of this project.

The information about the location of the cities, roads and streets are in the OpenStreetMap (OSM) system (OpenStreetMaps, 2013), a collaborative maps system that has about 400 GB of information about all the places in the world and is freely available for download and use. Some examples of applications using OpenStreetMaps are show in Figure 1.

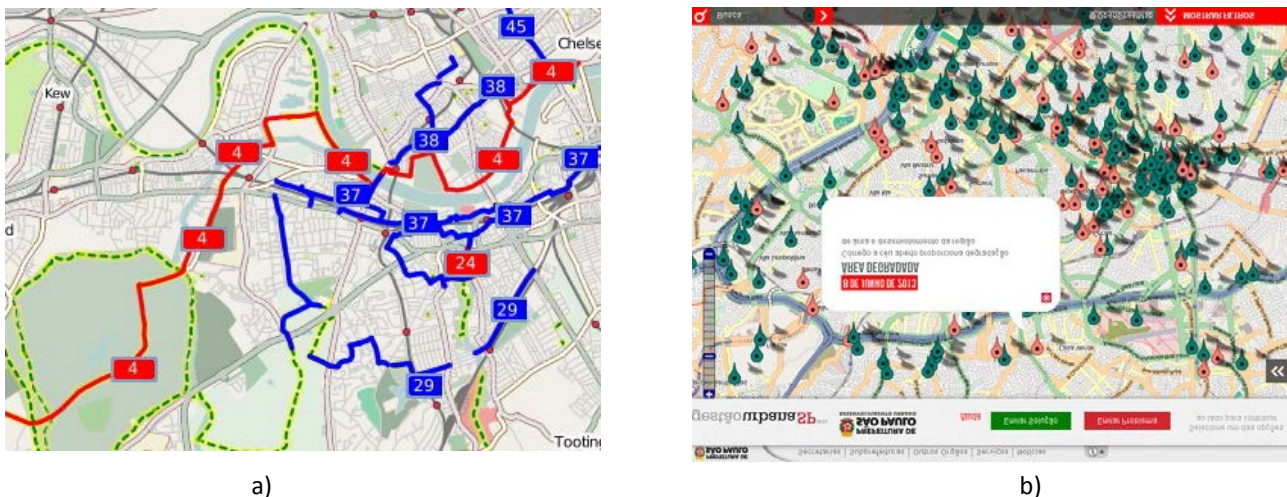


Figure 1: two application using Openstreetmaps: a) cycling routes in London and b) a collaborative management system in the city of São Paulo.

The data are stored in an XML file, in a standardized format that makes it easy to manipulate them by a software developed by students. In addition to the complete maps, one can use some tools also maintained by system users, like BBBike (<http://extract.bbbike.org/>), that allows the download a specific area of the map, as a block, a neighborhood or a city. This greatly reduces the amount of data that must be handled at once and ensures that students have flexibility in testing and using various data sources. Interesting to note that the tool is focused on bike

enthusiasts and serves mainly to export maps for different types of GPS devices. Of course, it is also possible to export the file in its pure format (.osm) which is actually an XML file.

Students have to develop their programs in C++ language, and they are allowed to use some specific libraries that can handle XML files, but all the rest must be developed by themselves. Finally, since the interest is on algorithms, no graphical user interface is required, although it is not prohibited.

2.3 Assessment

The final grade is a composition of two grades: practical and theoretical. The project assessment was made on a daily basis using rubrics and, for the theoretical part, the assessment consisted of two tests. Each part worths 50 % of the final grade. More details about the assessment procedure and the obtained results will be shown in the next session.

2.4 Working strategy

In this section, an overview of the entire process is provided, with some attention to the rubrics method used both to evaluate the students and to force some behaviours that we found to be convenient for the students.

2.4.1 Group formation

At the beginning of the semester, the students were divided in groups of 4. No specific role is assigned to each member of the group, so they are free to work in the way that is more comfort to them.

Ideally, groups should be formed with students of different profiles, both technical and personal. The problem is that this information is usually not available. Therefore, we decided to group the students in a randomized way, just trying to separate the ones that were obviously friends.

2.4.2 Problem understanding

The problem is then presented for the students, and as the first task, they have to gather the requirements for the project. Usually this is not an activity that students are very excited to do, and actually, they try to overpass this stage. Given the importance of in the real life projects, the way we found to obligate them to do it seriously was to grade the results: this one day activity worths 20 % of the total grade for the practical part of the course. The grading for the first day is made using the rubric shown below:

Table 1: Rubric for the first day.

GRADES				
CATEGORY	A	B	C	D
Problem understanding	Completely understood the problem, and started to develop strategies to solve it.	Completely understood the problem.	Partially understood the problem.	Poor problem understanding.
Text quality	Text very well written and organized, with ideas logically concatenated.	Text is well organized, with logically concatenated ideas.	Text reasonably well organized.	Confusing text.
Grammar	No grammatical error.	Maximum of 2 grammatical errors.	3 to 4 grammatical errors.	More than 4 grammatical errors.

This rubric sends a clear message to the students: a deep understanding of the problem is crucial for the problem resolution, but it is not sufficient. A good presentation of the ideas is also very important for the success of the whole project. As will be evident in the next sessions, in addition to assessment, rubrics are also powerful tools to induce some desired behaviors among the students.

2.4.3 Project development

In the next classes, students are required to work on the problem, developing strategies, testing ideas and writing and debugging codes. The role of the TA is both to help them with their difficults (like a senior developer) and to work as a project manager, controlling the schedule and the commitment of each one with the project.

The TA must be trained to not give answers to students: his/her role is to facilitate the process and not to make all the work for them. Therefore, choosing the right person and give him/her an appropriate training is very important for the success of this activity.

The students are continuously assessed during this stage, both as a group and individually. Soft skills are also evaluated, to give them an idea of how they are seen by their peers and by the professor. The rubric for this stage is shown in Table 2.

Table 2: Rubric for the development stage. The first two lines are for individual assessment, whereas the last line is for group assessment.

GRADES				
CATEGORY	A	B	C	D
Assigned tasks	Brought all the information that was required and some additional ones.	Brought all the information that was required	Studied the subject, but there were gaps.	Not studied the subject of which hre/she was responsible.
Participation	Actively participated in and led the discussions.	Actively participated in the discussions.	Attended some of the discussions.	Was oblivious to the discussions in most of the time.
Work progress	The group made much more progress than expected in solving the problem, compared to what was done in the previous week.	The group has made good progress in addressing the problem, compared to what was done in the previous week.	The group has advanced a bit in solving the problem, compared to what was done in the previous week.	The group has not advanced very little in solving the problem, compared to what was done in the previous week.

2.4.4 Final project evaluation

At the end of the semester, the students have to present their projects for the professor, the TA, and their colleagues. In this presentation, both technical and communication aspects are evaluated. The rubric used for oral presentation is shown in Table 3, whereas the one used to evaluate the technical aspects of the projet in shown in Table 4.

Table 3: Rubric for oral presentation.

GRADES				
CATEGORY	A	B	C	D
Comprehension	Student is able to accurately answer almost all questions posed by classmates about the topic.	Student is able to accurately answer most questions posed by classmates about the topic.	Student is able to accurately answer a few questions posed by classmates about the topic.	Student is unable to accurately answer questions posed by classmates about the topic.
Listens to Other Presentations	Listens intently. Does not make distracting noises or movements.	Listens intently but has one distracting noise or movement.	Sometimes does not appear to be listening but is not distracting.	Sometimes does not appear to be listening and has distracting noises or movements.
Time-Limit	Presentation time is within 1 min from the scheduled interval.	Presentation time is within 2 min from the scheduled interval.	Presentation time is within 3 min from the scheduled interval.	Presentation time is more than 3 min out of the schedule interval.

It is important to note that, the first two categories are for individual assessment, whereas the last one is for the whole group. The final grade for each student will be a combination of these two grades.

Table 4: Rubric for technical assessment.

GRADES				
CATEGORY	A	B	C	D
Relationship of the map with the XML file	The group comprised the file and made a relationship between the information and the map itself.	The group comprised the file but could not hold a relationship between the information and the map.	The group did not understand the file but sought to define the relationships between the file and the map.	The group neither understood the file nor attempted to make a relationship between the file and the map.
File import/reading	The software was able to read the file and made the correct relationship with the existing structures.	The software was able to read the file but the required structures were not implemented. and made the correct relationship with the existing structures.	The software failed to read the file but the group understood the existing structures and defined then at least partially.	The software failed to read the file read and the group do not understood nor defined the involved structures.
Information processing and display	The software exhibited the file information in a dynamic, cohesive and interactive way.	The software exhibited the file information in a simple but intelligible way.	The software failed to display the information but prepared a way to display the information.	The group failed to display the information and did not prepare any form of data presentation.
Use of linked list structure to represent the data structure	The group understood and made use of linked lists structures to feed and display information.	The group understood the linked lists structure but failed or struggled to implement it as a solution.	The group did not understand the system of linked lists, but tried to implement the system using it.	The group did not understand the data structure and failed to deploy it in the final solution.
XML importing	The group presented the map information held in data structures using XML as a repository.	The group presented the information using data structures but failed to properly handle the XML.	The group managed to deploy a static data structure, and/or failed to transpose the data from XML.	The group was unable to provide map information or manipulate the data through XML.
Arrange location information (meta-data)	The group extracted and organized location information in multidimensional vectors.	The group extracted the location information in multidimensional vectors haphazardly.	The group managed to extract location information, but failed to organize them.	The group was unable to extract the location information.
Information formatting change	The group information formatted in accordance with the needs of future treatment for the elements	The group formatted information, but some aspects of treatment were ignored.	The group was unable to format the information, but they understood the need for treatment	The group was unable to format the information and understand the aspects of treatment
Presentation of data in map form	The group formulated a cohesive way to present the information in a map.	The group sought to formulate a cohesive way to present the information in a map.	The group made an improper way to present the information in a map.	The group did not make a way to present the information in a map.

2.5 Soft skills assessment

At the end of semester, the students receive some feedback about their behavior during the group work activity. This is made by a rubric as well, but instead of being assessed by the TA, they are now assessed by their peers. The rubric used for this purpose is shown in Table 5.

Table 5: Rubric for group working assessment.

CATEGORY	GRADES			
	A	B	C	D
Contributions	Routinely provides useful ideas when participating in the group and in classroom discussion. A definite leader who contributes a lot of effort.	Usually provides useful ideas when participating in the group and in classroom discussion. A strong group member who tries hard!	Sometimes provides useful ideas when participating in the group and in classroom discussion. A satisfactory group member who does what is required.	Rarely provides useful ideas when participating in the group and in classroom discussion. May refuse to participate.
Quality of Work	Provides work of the highest quality.	Provides high quality work.	Provides work that occasionally needs to be checked/redone by other group members to ensure quality.	Provides work that usually needs to be checked/redone by others to ensure quality.
Attitude	Never is publicly critical of the project or the work of others. Always has a positive attitude about the task(s).	Rarely is publicly critical of the project or the work of others. Often has a positive attitude about the task(s).	Occasionally is publicly critical of the project or the work of other members of the group. Usually has a positive attitude about the task(s).	Often is publicly critical of the project or the work of other members of the group. Often has a negative attitude about the task(s).
Working with Others	Almost always listens to, shares with, and supports the efforts of others. Tries to keep people working well together.	Usually listens to, shares with, and supports the efforts of others. Does not cause \"waves\" in the group.	Often listens to, shares with, and supports the efforts of others, but sometimes is not a good team member.	Rarely listens to, shares with, and supports the efforts of others. Often is not a good team player.

3 Theoretical classes

As the semester progresses, the student demands for specific knowledge start to appear, and these demands are addressed in the theoretical classes. Therefore, the theoretical classes have changed because of these demands: the chronological order of the topics were changed to accompany the project issues. This also can be viewed as a paradigm change: before, the practical classes were considered as a complement for the theoretical classes, and their goal was to make the students better understand the concepts learned. Now, the course is centered in the project, i.e., practical classes, and the students look for useful information in the theoretical classes.

The course usually follows the sequence of topics suggested by (Cormen et al, 2001). Table 5 provides a rough idea of this change.

Table 6: Sequence of topics before and with the project inclusion.

Before	With the project
Complexity analysis	Complexity analysis
Algorithm design strategies	Graphs
Sorting and Searching algorithms	Hashing
Hashing	Sorting and Searching algorithms
Graphs	Algorithm design strategies
Geometric algorithms	Geometric algorithms
String problems	String problems

This change did not cause problems for the students in understanding the topics. In fact, due to the greater correlation with the practical part, they showed to be more motivated and participated more actively in theoretical classes. Questions that never were posed by the students started to happen, and the classes become much more interesting, both for the students and for the professor. Also, it was not unusual to have some classes totally modified because of the students demands in some specific points of the project: several times, the professor had to alter the schedule class to meet the demands of the students.

4 Contents coverage

Although it provides an interesting background for some of the topics that have to be covered, it is clear that this project do not cover all the contents.

Recognizing the importance of practice of all topics by the students, we assigned smaller projects including the remaining topics. These projects were assigned as part of theoretical classes.

The students were allowed to work on these exercises in groups, but they are required to present the their solutions individually for the professor, who make some questions to ensure that they really made the exercise instead of simply copying the answer from a colleague or from the Internet.

This strategy also helped to keep the interest of the students in the class. The topics that were covered in this way are: algorithm design techniques, hashing, strings problems and geometric algorithms.

5 Final comments

In this paper, an experience using maps as motivation for the practical classes of Algorithms for sophomore students of Computer Engineering was presented.

The first issue that the students have to deal with is the manipulation of XML files using a programming language (C++ in our case). The students are told that there are some libraries that can handle XML files but no other clues are given: they have to solve this problem by themselves. At first it is clear that students are lost with this new approach: accustomed to being recipients of content, they are surprised to realize that any new development should be done by their own hands. However, after a few weeks, they start to move on by themselves and, at the end, all of them made their way to solve the XML problem.

The rubric strategy for grading showed to be very effective in two ways: it shows the students what will be assessed and also shows the demand level of each assessed parameter. It really provided a change in most students: after a bad grade in a class, they usually change their behavior because they know in advance the consequences. This rapid feedback works very well for this Y generation students. In fact, most of them said that they feel more comfortable with this assessment system than with the traditional way, used in theoretical part, with only 2 tests during the semester. They argued that, with constant feedback, it is possible to rapidly recover a bad grade.

Some elements of related courses, like Software Engineering, were also included in the projects: requirements elicitation, schedule planning, are some examples. We hope that this interdisciplinarity aspect helps the students to have a more global view of the entire course they are attending to.

Group formation showed to be crucial for the success of this initiative. We noticed that groups with more than one leader tend to engage in fruitless discussions. Observing the discussions, we noticed that most of them had little to do with the real problem to be solved; they were more often generated by the power struggle between the leaders. On the other hand, groups without a leader tend to stay inactive, with no clear direction of what to do next.

This experience is being conducted for the first time in this semester, so the final outcomes are not yet available. Some things that we have observed are that the students in general are very excited with the project and they are more participative in the theoretical classes. We really expect that this experience will produce good results at the end.

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The Use of Computer Simulation for Teaching the Concepts of Operation Management for Attract and Maintain Students in the Production Engineering Course

Tárcia Portela de Carvalho Correia, Heráclito Lopes Jaguaribe Pontes, Marcos Ronaldo Albertin, Pedro Celestino de Oliveira Neto

Universidade Federal do Ceará, Brasil
Departamento de Engenharia de Produção, Centro de Tecnologia, Federal Universidade Federal do Ceará, Campus do Pici, 60455-900 - Fortaleza, Brasil

Email: tarcia@ot.ufc.br, hjaguaribe@ufc.br, albertin@ot.ufc.br, pedrocelestino2@gmail.com

Abstract

The Production Engineering is the engineering that has undergone significant growth in the last years in Brazil. This results from the fact that the production engineer is a professional with skills to integrate technical and managerial issues and/or because the huge growth of organizations. This paper arose from the realization of lack of knowledge about the responsibilities and attributes of the production engineer by the students. This paper proposes to use the computer simulation to teach concepts of Operation Management (OP) for attract high school students and maintain the undergraduate students in the Production Engineering Course. This work presents the concepts of OP from the development of models in basic, intermediary and advanced levels employing computer simulation through Arena's software. With this project, is expected that the students learn about production engineering, their fields of expertise and its prominence in businesses and to develop student's skills in simulation software.

Keywords: teaching of operation management; production engineering; computer simulation; arena's software

1 Introduction

1.1 Motivation

Brazil is a developing country where the engineering graduation plays a crucial role speaking of generation of opportunities for young people, especially those in social-economic disadvantages. Paradoxically, along with the levels of unemployment, the labor market lacks people with specific training or who are able to perform in areas typically related to higher education engineering degrees.

Production Engineering is currently one of the most dynamic and challenging professional areas in engineering. This engineering degree has been significantly growing in recent years in Brazil. Its techniques and methods have shown their value in the last century, which can be proven by the large increase in industrial productivity. This has been happening because the production engineer is a professional able to integrate technical and management issues, making this professional a key in the labor market.

In the state of Ceará, Northeastern Brazil, it's noticeable that high school students, production engineering students in potential, are unaware of the Production Engineering areas and its attributions. Also, in the early years of the program, the amount of students leaving the degree is high, due to the lack of practical learning of the area where they'll work in. Production Engineering is divided into sub-areas and Operations Management (OP) is one of the most complex and important areas of the course.

According to Constantino et al. (2012), students have difficulties to understand the complexity of the Operations Management (OM) subject. The multiple and competing objectives that are linked to the OM decisions are not obvious to people and students that do not have experience in a company operations as students generally have not obtained yet this experience. The theoretical knowledge that OM students acquire in classrooms does not give them full awareness of OM issues or the criticality of the decisions of operations managers.

1.2 Scope

Innovation comes as a response from the institutions to a current labor market getting more dynamic, complex and competitive. Science and technology are increasingly present in society on a daily basis, becoming subject of ethical and political development debates (AUDY, 2007). Thus, technology can be an element to defeat deficiencies in engineering, teaching, encouraging teamwork and creating links between theory and practice (RAMBALDI, 2009).

This work proposes the use of technology, but specifically of computer simulation, for the process of active education to high school students and undergraduates, to promote the development of cognitive skills and to explore learning in an interactive way.

To make this possible, a computer simulation software was applied, in order to show and teach notions related to operation management, a key area inside Production Engineering. The discussed concepts of Operation Management were: types of production systems, production planning and production control, production management and operational research and; facility layout. The work was developed from a research project, with support from the Federal University of Ceará, the public high school and the National Council for Scientific and Technological Development (CNPq) to explain the concepts of operation management to public school students from the Fortaleza City, capital of State Ceará, Brazil.

The study intended to make learning active with the creation of virtual models that mimic real production systems, presenting what are the necessary decision-making everyday situations in the routine of a Production Engineer. From the construction and analysis of these models, the students could understand the significance of operation management in companies, and they also suggested improvements to these models through changes in input parameters. At the end of the work a questionnaire was developed to evaluate the strong and the weak points related to the project, and a positive feedback could be noticed in this experience. By all means, there are intentions to extend this proposal to other audiences, given the importance of this practice.

2 Literature Review

In this section, there is a review of the literature, detailing the importance and difficulties of teaching engineering and production engineering, as well as the differentials with the use of computer simulation for teaching.

2.1 Education in Engineering

According to Zavalani and Kaçani (2012), challenges in modern engineering practice, posed by system complexities, require a range of multi-disciplinary, physics based, problem-matched analytical and computational skills from engineers. Engineering curriculum are abstract objects to some undergraduates because they are closely associated with working, practice, a lot of apparatus and project systems which are not been seen in our living while broadly applied by industries (HUANYIN et al., 2009).

To Colenci (2000), teaching engineering involves a high degree of complexity, because it carries the responsibility of the full educational and professional development of the student beyond their maturity as a human being. Pedagogical practices along with experience allow to ensure quality learning results.

According to Belhot (2005), engineering degrees emphasize the technical preparation of the student, when they should actually focus on market relations. The assignments taking place in the classroom are about solving well structured problems that aren't urgent, only within the deadline stipulated by the teacher. The internship does not provide a full personal and professional development. All these factors reflect on basic deficiencies of the engineering degree, such as low interpersonal communication, lack of motivation for working in group and the missing link between theory and practice.

Carvalho, Porto and Belhot (2001) call attention to the importance of Engineering Schools preparing their students to face changes, to search new knowledge, identifying what is relevant, leading properly what they have learned to practice, not limiting themselves to just learn concepts and formulas, but getting results that are differentials.

2.2 Education in Production Engineering

Cunha (2002) points out that the advent of production engineering with a managerial component resulted from knowledge of processes and from problem solving inside the organization, typical engineer attitude, which is not the focus of administration and management courses. This differentiation makes this professional able to deal with problems related to the mobilization of technical resources.

According to Faé and Ribeiro (2004), the current situation of production engineering points to a increasing growth of degrees in the past few years, followed by a large movement of exchange of emphasis.

Piratelli et al. (2004) suggests, relying on the definition of the Brazilian Association of Production Engineering (ABEPRO), that production engineering should be placed in an area among the technological fields of engineering, humanities and social sciences and computing and mathematics.

To Magalhães et al. (2008), the progress of Production Engineering has been following the trends in the market and in educational systems, which implies the adoption of new concepts and principles in production engineering education that are more compatible with the current requirements and future labor market.

Batalha et al. (2008) states that, to learn production engineering in a practical manner, the engineer must learn how to create models that support the processes of decision-making about production management. A model is a simplified representation of a reality. The models are used to solve the complex problems that companies could have.

2.3 Computer Simulation

According to Goldsman (2007), the importance of computer simulation to improve the skills of students, exemplifying his study with the application of simulation as a teaching resource at high school level. For Prado (2010) computer simulation is a technique of solving a problem by analyzing a model that describes the behavior of the system using a digital computer.

Simulation is a computer based modeling approach which uses a chain of cause and effect relationships to help the user build complex models from the ground up one link at a time (Ambiye et al. 2005). The simulation can foresee with some confidence the behavior of a system based on the specific inputs and respecting the conditions. And it is a tool for analyzing scenarios; it uses only algorithms, but it does not replace the human being (CHWIF and MEDINA, 2010).

For Cox, Smith and Dimitratos (2006) state that with the use of simulation, a great variety of tasks can be performed and, as a virtual model, it becomes dynamic and easy to maintain. The simulation plays a significant role and can be used to design a new process, for solving problems of an already existing one; it can be used to test the efficacy of a new control and for the construction of a case study to see how much improvement adds value to a particular process. Although these tasks can be performed without a model, having a true to reality photo of a process readily available, radically changes the approach and countless possibilities can be used.

According to Greasley (2008), computer simulation is the representation of a process in which can be inserted different entities (people, pieces, products) that are linked to various attributes (workplaces, operating machines) interacting in a scenario, where different events happen based on real systems. These manipulations are responsible for generating results through numerous simulations that help to make decisions. Pasin and Giroux (2011) assert that the simulation has been widely used to analyze and to compare the system of scenarios, in order to improve the performance of the systems.

According to Tobail, Crowe and Arisha (2011), simulation modeling is actually used in several business fields and proved to be effective when it comes to examining the impact of different scenarios on performance results. The use of these methods encourages students and trainees to engage in new and innovative ways of thinking when it comes to production systems.

2.4 Computer Simulation for Teaching

The use of computer simulations in engineering science began over half a century ago, but only in the past decade or so the simulation theory and technology have made a dramatic impact across the engineering fields. That remarkable change has come about mainly because of developments in the computational and computer sciences and the rapid advances in computing equipment and systems (ZAVALLANI and KAÇANI, 2012).

Kincaid and Westerlund (2009) assert that simulation provides a safe environment that allows training cognitive and psychomotor tasks, allowing the increase the skills of a team without the risks of accidents or mistakes. They base their study mentioning applications of the simulation as training in several areas.

According to Satolo (2011), the use of simulation has been widespread as a tool to support education during the last decade. The use of educational games is a teaching alternative, because it allows discussing techniques by simulating the production process, in order to improve staff productivity and to increase the level of knowledge absorbed. This tool can make the student face real problems, which gives the teachers the opportunity to observe how their students analyze, learn, remember and think about a particular problem situation.

Siddiqui et al. (2008) stands for the benefits of using simulation in teaching. As they assert, educational simulation-based products are an excellent set of tools that offer features such as the visualization of the dynamic behavior of a real system. The use of these tools is quite effective in teaching, as well as it is one of the main methods of student-centered learning. Simulation allows students to practice their skills, such as critical thinking and decision making.

According to Silva, Pinto and Subramanian (2007) in Production Engineering, simulation software enables educational interaction, working as teaching facilitators. In other words, as pedagogical tools for teaching, its main advantage is the use of animations that promote greater understanding of the student, regardless of relative concepts of production systems in a practical situation.

Simulation environments are a privileged field for multidisciplinary activities in education. Simulators allow rapid and effective comprehension of complex concepts. A simulator has a major advantage over a text or a lecturer's explanation: interactivity. The students can "play" with different parameters and observe the results (ARNALDO et al., 2011).

3 Methodology

This work was developed through a partnership between a Public University, a Public High School and a National Council for Scientific and Technological Development (CNPq), with the purpose to detail the concepts of operation management, advantages and attributions of the Production Engineering professional, to build interest in High School students about studying engineering and to reduce the dropout of undergraduate students.

This project was undertaken from January to October of 2013; by six fellows: three from the University and three from the High School; during 4-hour meetings fortnightly; in the research laboratory for computer simulation and operation management in the University.

The Arena's® Software was used in this project. It performs the simulation of processes allowing doing analysis of operation management without interfering with the system. All and any modification in processes performed by the tool will only be modeled computationally and not with the real system. This is possible because all the defining characteristics of the real system are attributed to the software. This software provides an integrated graphical environment for simulation which contains all the features for process modeling, design and animation, statistical analysis and results analysis.

The research was classified as descriptive due simulation in education is a well-known and widely documented topic. The use of computer simulation (active learning) to teach concepts of operation management to the high school students and the undergraduate students to attract and maintain them in the production area was the challenge of this work. The development of this work was divided into steps. Below, the steps of this project are detailed:

1. Bibliographic Survey: A survey was conducted on the websites through the annals of publications of the main national and international engineering conferences, such as COBENGE (Brazilian congress of Engineering Education), ENEGEP (National Meeting of Production Engineering), SIMPEP (Symposium of Production Engineering), WSC (Winter Simulation Conference) and POMC (Production and Operations Management Conference). The goal was to assemble a database of articles that could describe methods and applications of computer simulation to engineering teaching, in particular those about the Arena® software. Publications within the last 10 years of each conference were selected, because, once the project is about software, old articles could be already obsolete and analyzing outdated versions of the software.
2. Teaching the Concepts of Operation Management: Trainings were conducted focusing on the main concepts of operation management, such as production systems, production planning and production control, production management and operational research and, facility layout. The students learned definitions in the training: lead time; difference between driven production and pushed production; theory of constraints; queuing theory and; systemic vision. These concepts were given to the research contributors, both high school students and university students. This was an important step to the high school students, once the essence of the Production Engineering degree was outlined, addressing the skills that a professional in this field should grasp and the functions this professional can perform. To the undergraduate students, it was an enlightening training that made them see the disciplines they're studying or already studied connected, working also to deepen their knowledge and unify the subjects they have learned, once the colleges are from different semesters.
3. Teaching the Computer Simulation and Arena's® software: Conducting training in Arena® software consisted of theoretical and practical classes. The lectures dealt with the historical simulation, existing

classifications (the types of variables, as the consideration of uncertainties and how to time), the advantages and disadvantages of their use, methodology for apply simulation and the main applications of the main window of the software Arena®, composed of bars and design tools. The classes were the development of models at two levels: basic and intermediate. Familiarity with building models of these two levels allowed working an advanced model.

At the first level designed a simple model which simulated a car wash for cars, where a client entry, wash stand and exit. The model shows in figure 1.

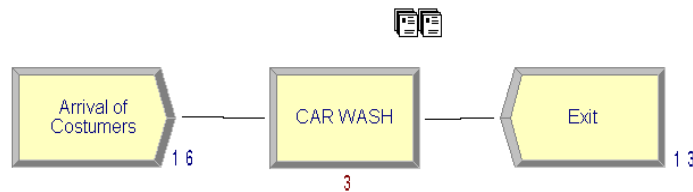


Figure 1 – Basic Level: Model of car wash

The intermediate model simulates a line at the bank where the customer chooses to go straight to the box or choose to speak with the bank manager. When leaving the management, the customer could leave or return to the checkout line. Upon returning to the checkout line, alter the priority of client service that came from management that he did not need to catch the end of the queue. After the service, the customer walks toward the exit. Note that unlike the first model, the level 2 included a number of possibilities and decisions. In Figure 2 has an intermediate model.

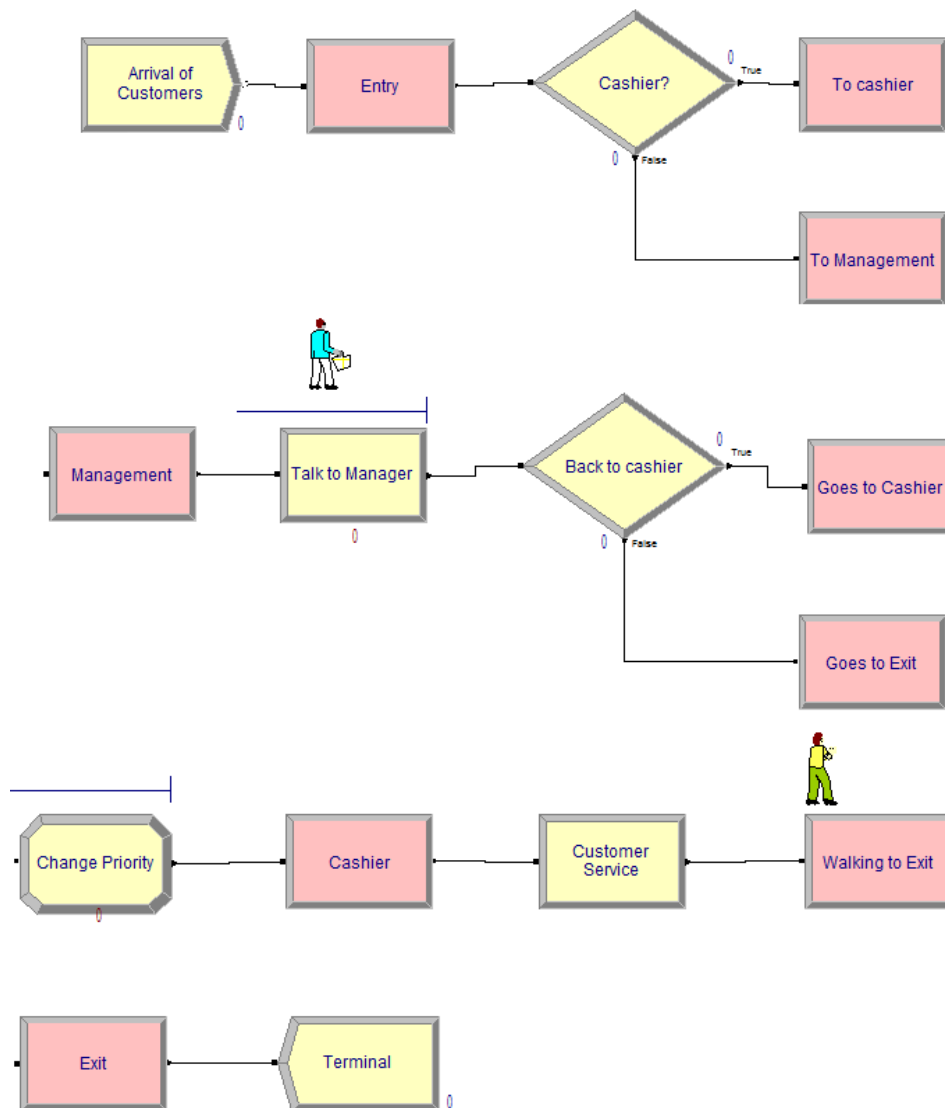


Figure 2 – Intermediate Model: Service model in bank

Finally, a more complex model would be applied, but it was necessary to field research in a real industry for a data collection process.

4. Date survey: To put into practice what was learned in the previous levels, it was conducted a field study that consisted of a technical visit by the project participants to a distributor of Liquefied Petroleum Gas (LPG). The observations that were made to obtain data on the production process of this company analyzed since the arrival of empty bottles to the output of those held by trucks with load capacity of 30 tons. The visit provided the access time data processes and probabilities for each part of the production. After this information was used to prepare a flowchart of the processes for better visualization and modeling

5. Manufacturing Systems Modeling: In possession of the data and the process flowchart built, started modeling the third level in the Arena® software, covering the following phases: discharge canisters, visual selection, washing and drying, expansion of weight, potting, conference weight, tightness test, paint booth, tagging and sealing and load the truck. The development of this model required more students because it has greater complexity than previous levels. The model is represented in Figure 3.

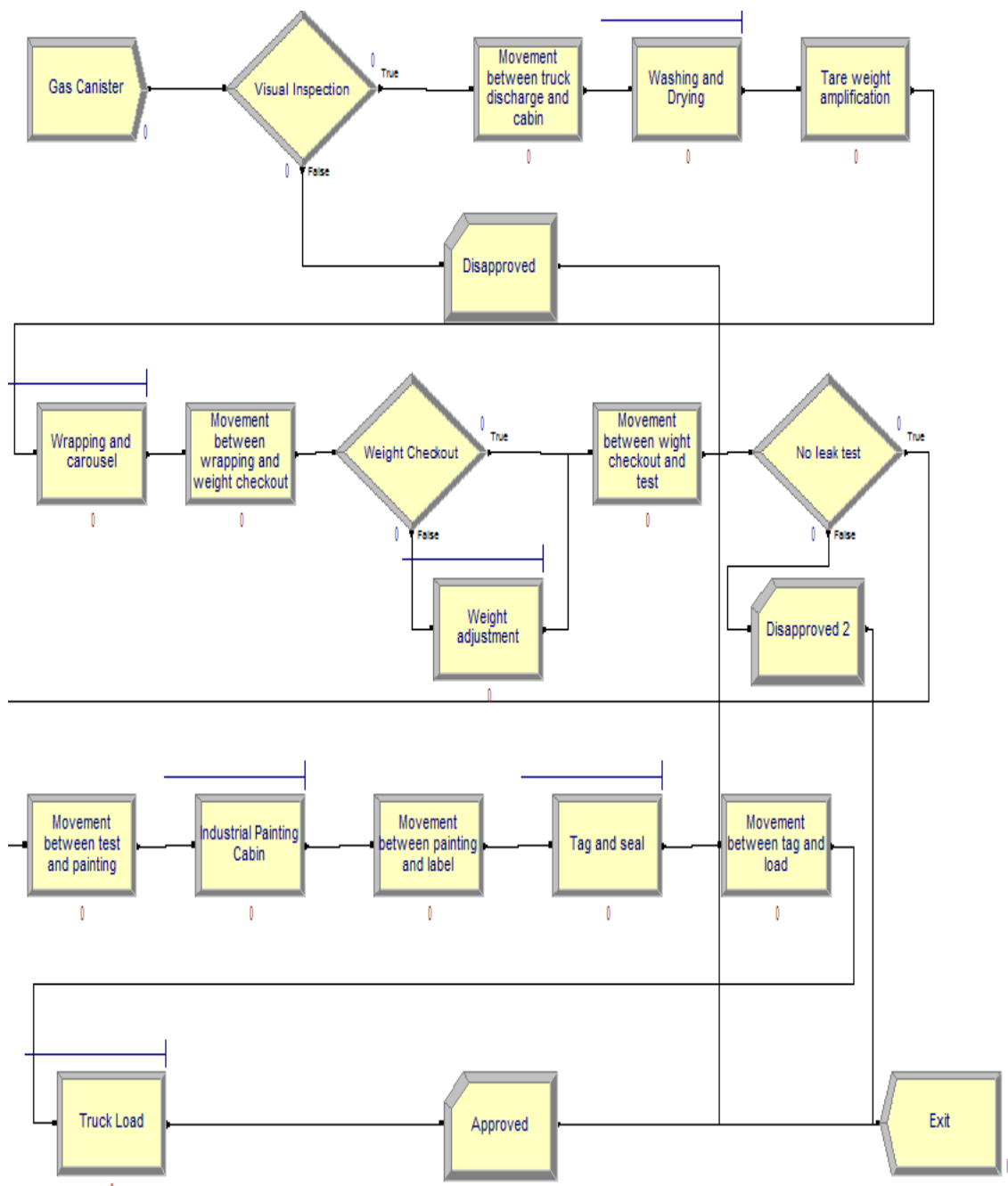


Figure 3 – Advanced Model: The production process in a factory gas.

6. Validation and Verification: After the construction of the third model, this one was presented to the company's production manager (who also knew the Arena® software), who analyzed and approved the simulated model, which was consistent with the current state of the process in the studied company.

7. Proposal of Improvements from the initial model of the Manufacturing System: After the stage of validation and verification, project participants individually developed hypothetical scenarios in Arena® software with suggestions for improvements to business productivity. Afterwards, a comparison was made between the group developed scenarios, then choosing the best result. This scenario was presented to the production manager of the studied company for possible future implementation. The production specialist of the company was interested to use the new model and was motivated to develop others works with area production students.

8. Analysis of the Project: For the analysis of the project, a questionnaire was developed for the high school students and undergraduate students. The questions that compose the questionnaire allowed to notice the level of knowledge of operation management in production engineering, the level of usability of the software, and the positive or negative perceptions of each scholar when speaking about the particularities of learning as a whole throughout the project.

4 Results

The results obtained in the questionnaire will be detailed in this section. The questionnaire consisted of fifteen questions, divided into: identification of knowledge, prior to the project, the participants of the project in production engineering and computer simulation; evaluation of the importance of training conducted in the project; evaluation of the use of computer simulation and software in the project development and; evaluation of the rate of importance of the project in learning the concepts of Operation Management.

4.1 Explanation of the Questionnaire

To identify the knowledge of participants before the development of the project in Operation Management, Production Engineering and Computational Simulation were applied three questions, listed below:

1. Have you ever had any contact with Production Engineering and Operation Management and its working field before?

☐ YES ☐ NO

Justify: _____

2. Have you ever had any contact with Computer Simulation before?

☐ YES ☐ NO

Justify: _____

3. What was your opinion about Production Engineering (Operation Management) and Computer Simulation before the project?

To evaluate the trainings in Operation Management, Computer Simulation and Arena® Software, three questions were asked:

4. Was the training in concepts about Operation Management and Computer Simulation clear and useful to develop the project?

☐ YES ☐ NO

Justify: _____

5. Was the training in the Arena® Software clear and enough to make use of the software in the project?

☐ YES ☐ NO

Justify: _____

6. The accompanying teacher's use of the software was essential for the development of the project?

☐ YES ☐ NO

Justify: _____

To evaluate the use of Computer Simulation and Arena® Software in learning the concepts of Operation Management four questions were developed:

7. The Computational Simulation added something positive in your training?

☐ YES ☐ NO

Justify: _____

8. What are your difficulties with the software? Indicate below with an "X ":

☐ The software isn't easy to install.

☐ The software is in another language.

☐ The software has many tools for learning.

☐ The software is complicated.

☐ The software is not properly licensed and your computer crashes.

9. The Arena® software was important for learning the concepts of Operation Management?

☐ YES ☐ NO

Justify: _____

10. From 0-10, 10 considering the highest grade, the degree of representativeness that you attribute the use of computer simulation and Arena® software to help learning of Operation Management?

☐

To assess the degree of importance of the project in learning the concepts of Operation Management were developed three questions (11, 12 and 13) for all participants and developed a specific question for each category of students: high school students to the question 14 and for undergraduate students to the question 15. The questions are listed below:

11. After the development of the project, what is your opinion on the current course of Production Engineering?

12. The use of computer simulation was motivating in learning the concepts of Operation Management?

☐ YES ☐ NO

Justify: _____

13. From their knowledge developed throughout the project, would you participate in a similar project again?

☐ YES ☐ NO

Justify: _____

14. As a student in high school , about to enter a university, the use of computer simulation software Arena® and sparked interest in your choice through the course of Production Engineering?

☐ YES ☐ NO

Justify: _____

15. By learning and applying the concepts of Operation Management with the use of computer simulation and Arena® Software, you feel more motivated to continue studying this course?

☐ YES ☐ NO

Justify: _____

4.2 Results of the Questionnaire Application

In this section we analyze the responses to the questionnaire of the research participants. The analysis will be divided as coverage of the following questions:

- Analysis of the answers to questions 1 to 3: The undergraduate fellows knew what was Operation Management and Production Engineering and had opinions and statements on the course, such as "operation management is one of the most important area of the production engineering", "comprehensive engineering", "with wide area of expertise" and "interesting area with many concepts that can use in day by day". As for the high school students did not know the course and their areas of expertise. All project participants were unaware of Computer Simulation;
- Analysis of the answers to questions 4 to 6: All students answered the three questions YES. The trainings were conducted in four modules divided into sixteen hours each: Concepts of Operation Management, Computer Simulation; Arena® Software and Applications Computer Simulation with Arena in Production Engineering (Manufacturing and Services). All models developed in the project: basic, intermediate and advanced were developed by students, but with accompanying teacher's questions about the software and clarification of concepts in the area;
- Analysis of the answers to questions 7 to 10: The responses were positive about simulation; all students responded that simulation training brought something positive, useful features like highlighting, dynamic and intuitive. The ability to actively learn was highlighted in the responses. About to the software, the responses were positive also "complete software", "important to facilitate understanding of the logical and visual processes". It was unanimous among the participants to list the many and varied software tools as considerable difficulty. Only one participant (high school student) related how difficult the fact of the software to be in another language. All students agreed that the use of the software was important in the learning and consolidation of the concepts of Operation Management. Also commented that helps "visualize what was seen in theory "and" understand the process as a whole and the possible problems that may arise. Half of the participants (three participants) attributed the highest score (ten) to help learning done by computer simulation and the Arena® software. Two participants gave a score nine and two eight independently rated;
- Analysis of the answers to questions 11 to 15: The high school students expressed very positive opinions regarding review of Production Engineering course after the project as: "found the production engineering multidisciplinary" and "developing a systemic view of operation management". The opinions of the students about the course you are doing are different: "operation management is very important for the market", "excellent broad- stroke", "is a course that adds much in the labor market", "the course is a great choice". All participants reported a special motivation in learning the concepts of Operation Management with the use of computer simulation. Stated justifications as "the project was possible to consolidate concepts seen in class is very important". The percentage of high school students who choose to do the course Production Engineering developed after the project was 100 %. After the project, all undergraduate students feel more motivated to continue the course.

5 Final Considerations

Production Engineering is a profession with a large market segment due to its multidisciplinary nature. But that engineering needs to be more widespread among high school students, especially in public schools, so that they can opt for a course in higher education. Furthermore, avoidance courses are high due to the limited possibilities of the students has to learn actively, making the course theoretical and difficult to understand.

One way to publicize and explain the concepts of Operation Management in Production Engineering was a joint project between the university and high school. As the Production Engineering has a very practical vies, this project was accomplished with the application of a practical tool (computer simulation software) and with a real company visit for data collection and modeling of its production system, which generates an extra motivation for the students who participated in the project

This work reached its goal when got positive feedback from the project participants. The high school students who were unaware of production engineering, detailed in the questionnaire their excitement to come to attend the production engineering course. Undergraduate students say they are more motivated to continue on its course from the consolidation of concepts seen in the classroom and understanding of a new tool in the area.

Computer Simulations have been found to be very useful for students. To be able to develop and evaluate modeling and simulation results, students should make use of their knowledge acquired in the project. The positive feedback obtained from students encourages us for the success of this approach in the future.

Since the project was implemented in a public school it will open space for other schools to have access to information about the project through its teachers and students, which will arouse the students' interest by seeking more information about the course of Production Engineering.

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Acknowledgements

The authors would like to acknowledge the financial support from CNPq (National Council for Scientific and Technological Development).

Application of Problem-Based Learning in Teaching Analog Electronics

Rodrigo A. S. Braga^{*}, Fabiana C. Guedes^{*}, Fernanda R. da Silva^{**}, Eduardo Moreira Vicente[†]

^{*},^{**}Federal University of Itajuba, Campus Itabira, Itabira, MG, Brazil

^{*}Research Group on Applied Computing Engineering

^{**}Research Group on Applied and Computational Mathematics

[†]Federal University of Sao Joao Del Rei

[†]Center for Research on Power Electronics and Electronic Systems

Email: rodrigobraga@unifei.edu.br, fabiana.costaguedes@unifei.edu.br, fernandasilva@unifei.edu.br, ufsj.eduardo@gmail.com

Abstract

Higher education in engineering in Brazil has undergone a discussion about pedagogical methodologies, since the traditional expository method has no longer motivated students and teachers, presenting poor results in the training of students. Much has been debated on new practices of teaching and learning that, in addition, consider the development of other skills besides technical abilities. In this context, the Problem-Based Learning, PBL, was implemented in the discipline Analog Electronics that belongs to the curricular structure of three engineering courses at the Federal University of Itajuba, Itabira Campus. The results show that PBL was able to increase student approval rate, teachers and students' motivation, and developed technical and personal abilities.

Keywords: Problem-Based Learning; Analog Electronics; Engineering Course.

1 Introduction

The training of engineers has been much discussed in the last few decades; many of these discussions address the use of active learning methodologies. The purpose of these discussions is to innovate pedagogical practices by changing the teaching and learning model; seeking to graduate technically qualified engineers with the appropriate human and social skills demanded by the current market (RIBEIRO, 2005).

Notably, the traditional approach of teaching and learning predominates in engineering education due to structural, cultural or even individual reasons, where the vision of work division and segregation among knowledge generates a higher education in engineering with a linear, cumulative and inflexible training pattern found in many curricular structures (RIBEIRO, 2005; VILLAS-BOAS et al, 2012). In addition, it is noticed that, in the context of higher education, the didactic training is deficient and undervalued (CUNHA, BRITO & CICILLINI, 2006). Therefore, the traditional teaching method creates a cyclical flow, since it is how current teachers were trained.

Another aspect is that the teaching, learning and evaluation methods used for engineering education poorly exploit students' active role in the teaching and learning process. These circumstances denote that even basic aspects of youth and adults education, andragogy, have been neglected in these courses. Andragogy presupposes a learning process in which the needs and desires of learners are the basis for the work (Knowles et al, 1998). Considering these andragogy principles and current students' age group in engineering courses, it is possible to identify that active learning methodologies fit these principles.

This scenery, in which engineering education is essentially performed in the traditional way of teaching and learning, i.e. teacher-centered, is found at the Federal University of Itajubá, Itabira Campus. Students are, in their majority, unsuccessful under this context whereas they are poorly motivated and interested in the way knowledge is transmitted (BOOTH & VILLAS-BOAS, 2009). Likewise, teachers who received feedback from these students became unmotivated inside the classroom.

To break up this scenario, the adoption of a different mechanism of teaching and learning was conducted in one discipline. This paper briefly describes this experience, using Problem-Based Learning – PBL (Savin-Baden, 2000), in an Analog Electronics course from three engineering curriculums: Computer Engineering, Control and Automation Engineering and Electrical Engineering at the Federal University of Itajubá, Itabira Campus.

One of the goals of this work is to justify the PBL choice, describing the methodology used in classes, the evaluation methods, relate the feedback from students, the impressions of teachers and discuss the results reached. Another objective of this work is to reply to some questions on the use of PBL as: Can students get approved in the discipline? Can they absorb the knowledge expected for a student in Analog Electronics? Using problems as study guidelines, can students integrate the concepts seen in Analog Electronics? Can students integrate Analog Electronics with other disciplines previously offered in the engineering course? Will students be able to develop other skills in addition to technical expertise? Will students be able to plan practical laboratory experiments without the help of a road map? Would this approach increase students' interest in Analog Electronics? Are students' capability and reliability when working in groups better than when working alone?

This paper is organized in eight sessions, including this introduction. The second session illustrates the scenario which motivates the application of PBL and the third summarizes the pedagogical ground behind the methodology of teaching and learning applied. In session number four, it is described how the activities of the discipline were conducted. Session five is dedicated to analyzing the students' feedback on the activities of the discipline. The results are discussed in session six, finishing the paper with sessions seven and eight, where are the future work and conclusion respectively.

2 Motivation and Justification

Analog Electronics belongs to the curriculum of three engineering courses at the Federal University of Itajubá, Itabira Campus: Computer Engineering, Control and Automation Engineering and Electrical Engineering. Around 150 students enroll in this course a year but, on average, only 57% of the students are approved. All the teachers responsible for this course report the same experience on how the discipline is taught and how students behave during activities.

Before the approach using PBL, this course was taught in a traditional way, with theoretical and practical classes. In this traditional way, during the theoretical classes, the teacher was the holder of knowledge and gave a lecture using a courseware based on a basic bibliography. During the practical activities, students followed a lab road map, with bounded and well defined tasks; this kind of activity had the intention of linking the theoretical and practical aspects helping students to assimilate the concepts of analog electronics.

In this scenario, students did not get involved during the lecture, they assumed a passive posture and there was no study routine. This lack of study routine implied in bad evaluation test results, since students were unable to assimilate all the necessary knowledge to get approved in the course. During practical activities, students were not free to try other solutions other than those described in the road map, this fact implies that they cannot learn from mistakes and the reports on the experiment are just the same as those elaborated by other students in previous years.

For teachers, the frustration of failing to achieve the main goal, make students absorb the knowledge, was just one of the factors that motivated the adoption of a new teaching method. Considering the scenario described for students' behavior in the traditional method, teachers became unmotivated and, after the first discipline evaluation test, watched many students abandon the course. From the other students that went ahead with classes only a few were approved after completing all the discipline activities. This perspective motivated the adoption of PBL, reported by Ribeiro (2008) in the discipline of Management Theory adapted for teaching Analog Electronics.

3 Pedagogical Ground

In order to choose the methodology to be applied in Analog Electronics, teachers targeted one (i) where the teaching and learning process was student-centered, (ii) that considered the different learning styles that can be present inside a classroom and (iii) also developed other skills as oratory, writing techniques, presentations to small groups, reliability, ability to work in teams and others.

Some of these preferences are supported by the constructivist theory, following the socio-interactionist model proposed by Vygotsky (VYGOTSKY, 1978) where the learning process of an individual is directly related to his external environment interaction. This external environment is composed by objects and other individuals and

from the interaction between an individual and the environment; this individual, here referred to as student, should build his own reasoning and knowledge, not only memorizing "right" answers and reproducing another person's directions.

Different learning styles can be understood as the way an individual perceives, processes and retains information (KURI, SILVA & PEREIRA, 2006). Felder and Silverman (1988) define learning styles as preferences in the way an individual perceives, captures, organizes, processes and understands the knowledge and/or information. They synthesized a model with five dimensions of learning styles: Active/Reflective, Sensory/Intuitive, Visual/Verbal, Sequential/Global and Inductive/Deductive.

After an investigation into the active learning methodologies used in high education institutions in Brazil and around the world, the applications of class discussions, seminars, problem-based learning, project-based learning, case study, simulations and conceptual map, discussed by OLIVEIRA (2012) were found. In addition to these methodologies, it is worth mentioning the techniques of peer instruction, just in time learning (ARAÚJO & MANZUR, 2013) and team-based learning (MICHAELSEN & SWEET, 2008), in-class exercises, cooperative note-taking pairs, thinking aloud pair problem solving, minute paper (VILLAS-BOAS et al, 2012) and group dynamics (SILVA, 2008) already present in some Brazilian engineering education institutions.

Within these possibilities, the PBL - Problem-Based Learning was chosen, as this methodology of teaching and learning is characterized by the use of real life problems to stimulate the development of critical thinking and the abilities to solve problems, acquiring fundamental knowledge concepts from the area under study (RIBEIRO, 2008). PBL has similarities with many learning principles proposed by Ausubel, Bruner, Dewey, Piaget, Vygotsky and others (DOCHY et al, 2003), creating conditions for a collaborative student-centered teaching and learning process following the socio-interactionist model (SAVARY & DUFFY, 1998); it meets the criteria desired by teachers. So, as PBL methodology may include several activities types to solve a problem, it can contemplate many learning styles in these activities in which students can have many opportunities to acquire concepts and knowledge.

Even on hard structured formats, PBL favors the development of essential attributes for future professional life of students, as adaptability changes, solve uneventful problem ability, creative thinking, team work, ability to identify strengths and weaknesses points, commitment to continuous learning and improvement, reliability and initiative (RIBEIRO, 2008). Still following Ribeiro (2008), PBL contributes to conceptual and investigative training of students, allowing the improvement of communicative and interpersonal skills necessary for professional practice.

4 Problem-Based Learning Applied to Analog Electronics

This course was taught with four theoretical lessons and two practical classes per week. In the experiment, the class had 80 students that were divided into 10 teams of 8 students each. The theoretical meetings happened twice a week, while there were five laboratory meetings; totaling 14 hours of professor availability to students.

The teaching and learning activities were planned considering the knowledge that students should acquire after coursing Analog Electronics and the skills that they should develop. Later in this paper, these knowledge and skills will be described in more details. Teachers also took into account the resources that students should have access to complete tasks, such as books, papers, electronic components, laboratory instruments among others.

4.1 The Problems

The problems were the focus of the method, in them were contemplated the entire syllabus knowledge, divided into 8 problems. All the problems together led students through learning the operation of diodes, rectifiers, transistors and small signal amplifiers to build a unique design for power supply, and an amplifier circuit at end of the course. To solve most of the problems, students should pass through theoretical training, computer simulation, practical experiences and understand the theory limitations. Understanding the functioning of these components in this context is required for a student to get approved in analog electronics.

In the problems construction, three things were highly observed. Firstly, the concepts that students should have understood about a topic were listed, and the teachers established the final product that the students could get at the end of the process. Here is noted that the final product was not limited, many solutions to the same problem

were allowed; students could get unrestricted correct answers since they had researched, comprehended and applied the concepts required that grounded the solution. The objective was to enable students to find and choose the best answer in their own judgment.

Secondly, the problems were written always creating intermediary goals for the students. Before achieving the main solution, students should pass several checkpoints, ensuring that they not only presented the solution, but understood all the background and the concept integration of knowledge behind it. These checkpoints also supported teacher's evaluation on the research done by the students.

Thirdly, teachers tried to adapt the problem to an enterprise context, where students could play the roles of leader, spokesman and editor. This scenario enabled students to develop skills such as problem-solving, flexibility, autonomous learning, initiative, reliability and handling many different tasks. All these characteristics in a team work are requested by employers (NCVER, 2003) and desirable in students.

Here is presented problem number two, used in the discipline, as a sample problem: *"After a meeting in an enterprise headquarters, in which the manager presented the power source project divided in blocks, the development department director requested the manager and his team to start projecting the electricity grid nearest block. The director, seeking for project alternatives, requested, at least, three circuit arrangements that meet the requirements of this block.*

So, the manager ordered the project of a half-wave rectifier circuit, a full wave bridged configuration rectifier circuit and a full wave rectifier using a center-tap transformer. For all the circuits, the manager wanted his team to perform computer simulations tests before running laboratory tests using loads lower than 1k Ω . After, the manager required that all the important data about each circuit arrangement to be collected and detailed (waveform periods, dc values, component costs, transfer current ability, peak reverse voltage, power dissipation, graphics and others). This would help choosing the best project alternative to be presented to the director.

The computer and laboratory simulations should be presented to the director, showing all the relevant data collected using figures, wave forms, limits values for current and voltage, projects costs and others, ending with a project suggestion".

4.2 Set-up with students

Since students had probably always been educated in a traditional model, it became necessary to give an explanation on PBL and the new approaches of teaching and learning they would be exposed to. According to (RIBEIRO, 2008), students had a resistance on new methodologies, especially when the new process apparently implies a load of extra work beyond what they used to face in most disciplines.

Therefore, the first course meeting was of great importance. In this class, the teacher showed the discipline subjects, as he did in traditional courses. After that, the teacher illustrated the traditional methodology showing the teachers' role, as the center of the teaching and learning process; the students' role, as passive information recipients and the institutional role, placing too many students in classes and expecting high approval rates with high quality. Then, it was showed to students the skills that the business world expected them to have and how the traditional way fails in accomplishing these expectations. Only after this contextualization, PBL was presented to students, showing how the methodology could be used to develop their skills while they acquire the technical knowledge required for a student in the Analog Electronics discipline. These steps were needed for students to understand, accept and, mainly, become motivated about this teaching and learning process.

The next step was to introduce students to the theoretical and practical classes' methodology, and the evaluation method that will be discussed in details in next sections.

The last stage of the first meeting was to form teams. This process attempted to create heterogeneous groups considering the academic performance of students. Ten teams were planned: the first best student was assigned to group one, the second best student was assigned to group two, until the ten groups had one start member. Then rounds were started and each group from one to ten picked out other students available in the classroom, until all the students had been assigned to a group; this formation should prevail until the end of the semester. The students from each team also signed a contract establishing rules for meetings, responsibilities and penalties for lack of commitment among members of the group, in which each of them would be aware of their responsibilities

with teammates and the allocations for the roles of leader, spokesman and editor. These roles intend to, in summary, work students' leadership, ability to present work and develop writing skills. The roles were rotated at each problem, so that all students have the opportunity to exercise the roles. The objective was to keep self-adjustable groups, so the students could develop their own organization.

4.3 Theoretical Classes' Methodology

The duty cycle was weekly for theoretical and practical activities. For the theoretical, it is presented what was proposed to the teams. In the (i) first week all the teams received the same problem and established which students would exercise the roles of leader, spokesman and editor. The students were oriented to discuss the problem with their partners and fill a partial report which contains a list of concepts that must be understood to solve the problem, the knowledge that the group already had and the new concepts to be learned that could help solving the problem. In the (ii) second week: The spokesman of each team presented a solution for the problem based on their research, comparing circuit simulations, practical results and theoretical aspects. The editor delivered a final report and the leader evaluated the work of each member of the group, during the activities to solve the problem, using a form. The teacher made a closure for the problem, complementing the presentations in case some concept had not been addressed or had been misunderstood by students. After that, the teams received another problem and the cycle started again. It was suggested that students followed the duty cycle, adapted from Ribeiro (2008), showed in figure 1, for each problem.

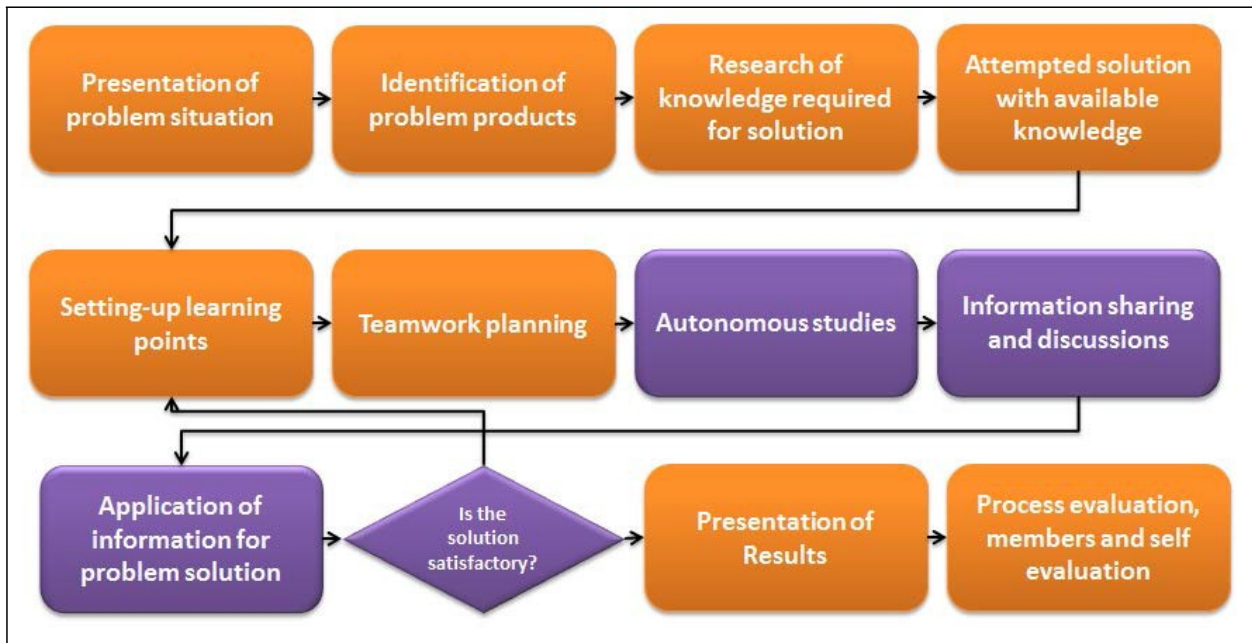


Figure 1 – Students' duty cycle

The final artifacts produced in theoretical classes were a partial report, a final report and a theoretical presentation. The partial report was adapted throughout the semester; these changes tried to ask better questions to students, leading then to better plan the work during the problem solving cycle. These questions can be summarized in which concepts they already have and new concepts they will have to learn that will assist in solving the problem. Also, the partial report asked about how they planned to execute the theoretical research, simulations and practical experiments. The final report should be composed by the results of the research, simulations and practical experiments with circuits' schematics, measurements, waveform and list of components used. In the theoretical presentation the spokesman showed to all class the results obtained by his team and the entire class discussed the solutions presented.

4.4 Practical Classes Methodology

For the practical classes, a similar approach was used. The main characteristic of practical activities was the absence of a road map. Students should develop their own experiments demonstrating in practice the solution for problems presented in theory. Teachers were available in the lab to assist students in the operation of some measuring equipment and power supplies. In the same way, the students' roles (leader, spokesman and editor) had similar actuation in the lab.

Students had complete freedom to choose the components, elaborate circuit diagrams, perform measurements, equipment configurations, instruments calibrations and all other activities found in a laboratory routine. This freedom associated with the absence of a road map allowed students to make a lot of mistakes, caused by many reasons like misunderstandings or misused concepts, bad equipment set up, bad configuration of measurement instruments, errors in circuit layouts among others things. In this ambient, students were always reviewing theoretical approaches, checking additional circuits, researching about electronic components in datasheets and many others actions to correct errors in order to get a satisfactory answer for the problem, proving the theory and its limitations using practical activities.

4.5 Evaluation Method

It is not an easy task to define an evaluation mechanism for generic competences, such as those developed by the approach used in the discipline. There are many efforts directly related to the process of competence assessment even for the technical and generic competences such as ethical behavior, responsibility, team work, creativity, initiative, proactivity, oratory, and others as reported by J. Fabregat (2009).

Despite this difficulty in assessing several important skill aspects, the evaluation intends to qualify instead of quantify the performance of students. For this reason, the traditional grade scale, from 0 to 100, was exchanged by a concepts grade. The concepts were (E) for excellent works, (G) for good works, (M) for works at average grade, (R) for the regular ones, (I) for those which were insufficient and (N) for not presented. Teachers believe that concepts are more significant for students, because the notion of (R) regular work is more perceptive than a grade 40 in terms of quality. But, to follow the grade system of the university, which is based in the traditional way of teaching and learning, these concepts grades were converted to the traditional grade scale at the end of the semester.

To compose the theoretical grade, it was considered the concepts obtained in the final report, theoretical presentation, leader evaluation and traditional theoretical test. The average of each type of activity had the same weight in the final grade, except the leader evaluation which had additional weight. The fact of giving more importance to the leader evaluation was due to an attempt to valorize students' behavior in team work and the skills they could develop in this environment. In the form used by the leaders, they should give concepts for themselves and the other members, considering aspects as participation in the group meetings, contribution to the technical discussions, willingness to perform tasks, presentation of relevant technical material and general behavior during teamwork.

Teachers also did not give up the traditional theoretical test with the purpose of comparing the performance between these students submitted to PBL methodology and those who were submitted to the traditional way.

To compose the practical grade, the concepts obtained at the practical presentation were considered. Teachers evaluated the link between theoretical aspects and experiment assembled, observing the spokesman's reliability in explaining the circuit based in theory, using the equipment and measurement instruments and presenting a critical parallel between the results expected in theory and the ones found in the practical experiment.

5 Educational Process Evaluation Form Analysis

During the discipline, students filled out, at the end of each problem, an evaluation form for the educational process. This form had 408 answers during the semester, where students praised, criticized and gave suggestions about the educational process. In the evaluation stage of the form, it was analyzed student's motivation for solving the problem, the problem's relevance for Analog Electronics, the integration of knowledge among the problems and other disciplines previously seen. Since the teachers did not provide the material, students also evaluated the

easiness for obtaining material. For professor's feedback, students answered about the time to solve the problem. The most important question was the achievement of educational goals, where students informed if they understood the problem and acquired the necessary knowledge to solve it. Table 1 presents a summary of the answers.

Table 1 - Summary of Answers to the Educational Process Evaluation Form

Evaluated Aspect	Excellent (%)	Good(%)	Regular(%)	Insufficient(%)
Motivation for solving the problem	50	42	8	0
Relevance for analog electronics	56	40	4	0
Knowledge integration	42	46	11	1
Easiness obtaining material	36	47	17	1
Time to perform the activity	35	43	18	4
Achievement of educational goals	40	49	9	2

Analyzing table 1 data, it is possible to see that students became well motivated to perform the task related to problems solving, 92% of them considered it good or excellent. Also 96% realized the problems relevance as good or excellent for Analog Electronics. One comment that reinforces these results was made by student 1: *"The teaching/problem was pretty interesting and useful, because we can apply the acquired knowledge in a practical and relevant subject and I believe that, if the method is well applied during the semester, we will have a good performance"*. And comment of student 2: *"The given problem is relevant for the studies required; it makes the group [...] commit itself in research and laboratory. The learning is being rewarding with this study method, very useful"*.

A similar result was obtained for knowledge integration (88%) and achievement of educational goals (89%), which measured the concepts understood and absorbed by the students, according to their evaluation. Another comment that exemplifies this was made by student 3: *"I noticed an interesting detail in this problem: we learned about the circuit autonomously, based on our experience and studies, not in the conventional way, in which we would listen to the teacher speaks and believe what he says. Learning this way make me feel more confident about my knowledge"*. Student 4 said that: *"The teaching method, particularly, is showing a very good result, because it "forces" students to learn by themselves for the project presentation. And since the problem is usually laborious, it cannot be done by only one student, forcing all the other members to work together.[...]"*

On knowledge integration, Student 5 described problem 8: *"Very special problem, very well done and with great knowledge integration rate, covering all the knowledge produced and accumulated in the course during the semester."*

Table 1 shows that students considered that it's not easy to obtain material. After an investigation about this fact in the form comments field, the students complained about the number of books and different titles to support the final problems, which were more complexes. Student 6 comments: *"I believe that the university should invest more in the diversity of electronics books. Basically, we have only 2 authors. As these are the main authors and there are not enough books for students to borrow for the entire semester [...] to teach a wider range of materials in the future with PBL, these new books will be necessary"*.

The result obtained with respect to the time to perform the activity was as expected. Similarly to that found in Ribeiro (2008), students point out the work load increase to perform tasks and that it was constant during all the semester, conflicting with other activities. This methodology aspect must be considered since it directly impact students' motivation to perform PBL courses and some approaches should be used to improve the students' ability to optimize the use of time to perform tasks.

Figure 2 shows the answers in the form comments field classified as positive, neutral and negative comments. Considering this important feedback from students, in general, they approve the implementation of PBL in Analog Electronics; 186 were positive feedbacks (46%) from a total of 408 answers. Other 82 comments (20%) were negative, while in 123 responses (30%), it was not possible to identify an opinion. Just 17 were left blank. Much detailed information was obtained through this form, but here is an overview of the answers.

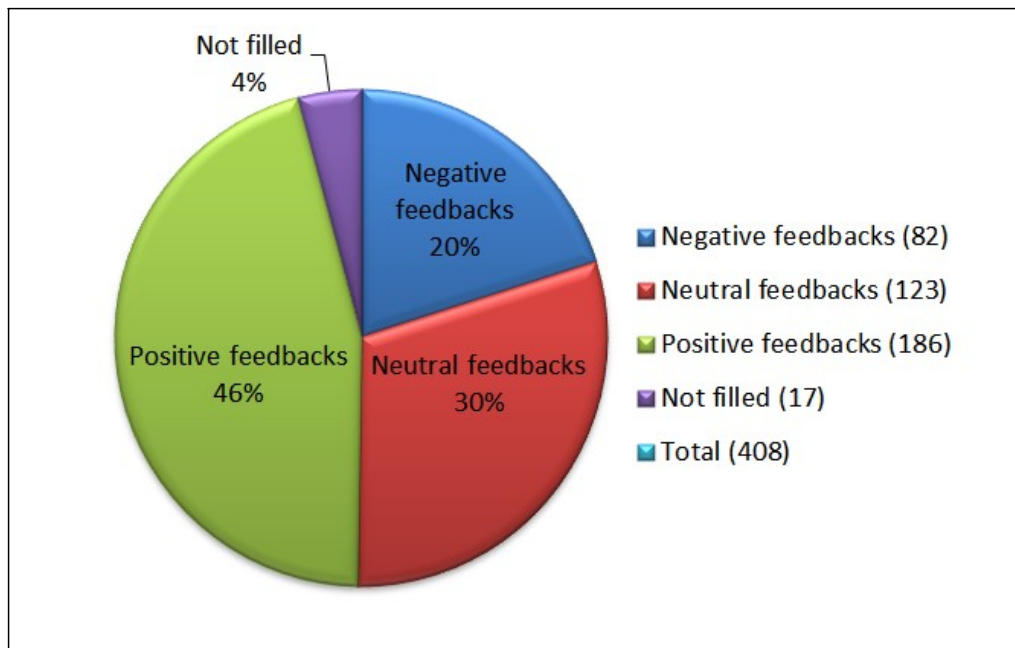


Figure 2 – Classification of comments on PBL implementation in Analog Electronics

6 Results

The results presented in this section were based on the impressions and discussions among the teachers involved in the discipline Analog Electronics, and teachers and students from other institutions during the internal Innovation in Engineering Education Workshop held at Unifei Itabira Campus.

6.1 Institutional Results

Considering the institutional interest in graduating all students joining the university with high quality training, the methodology developed in Analog Electronics is consistent with this objective. Taking into account the approval rate, 79% of students successfully passed in the discipline. Comparing with three previous courses offered where the approval rates were 46% (2nd semester/2012), 65% and 52% (1st semester/2012, two classes) and 68% (2nd semester/2011).

Another remarkable result was the discipline dropout rate. In the traditional way of teaching and learning, after the first theoretical test, about half of the students dropped out of the discipline. Using this methodology of teaching and learning, only 3 students dropped out of the course, all of them for personal reasons. In the institution's view, this means an effective use of resources (teachers, rooms, etc) allocated for teaching the activities.

6.2 Results for Teachers

From the teacher's point of view, based on the approval rates, the traditional theoretical test results and on the feedback from students, the knowledge expected for an Analog Electronics course was absorbed by the students. This fact was most noticed by teachers in laboratory classes where the questioning made and the interaction observed among students had never happened in previous courses offered.

Since students had the freedom to choose their own solutions for the same problem, teachers face many different solutions, sometimes additional studies were needed by the teacher to support some of the solutions presented by the students. Although this fact sounds uncomfortable, all the teachers reported this as a positive aspect of the methodology, since they could learn new things with the students.

In general, teachers reported that the amount of work increased, since students practically demanded full time support, but the quality of work became better. The new behavior of students, the growth of knowledge in the classroom and the results achieved made the teachers very motivated in teaching Analog Electronics. All of them considered the adoption of PBL as the main reason for the improvement in the course.

6.3 Results for Students

In the teacher's impressions, students have become more involved with the disciplines and created a weekly routine of studies. Leadership skills and oratory were also developed. It was possible to observe the improvement in terms of organization, since the students acquired experience in team work leading to better researches and final reports. The oratory also evolved during the semester, although students have presented only once as the spokesman, the presentations performed were getting better over the problems. The mistakes occurred in the first presentations were corrected by the teachers and, with these notes students learned how to make good presentations.

Another skill that evolved was the writing ability. The first final reports contained a huge amount of errors like spelling, formatting, presentation and interpretation of results and poor quality graphs among others. These final reports were corrected in detail and returned to students with all the feedbacks. The teams should rebuild this final report and resubmit it for correction. This process generated, at the end of the course, much better written, formatted, detailed and well technically presented reports.

Their practical ability improved as well. In these classes, students showed better results without a road map, performing various tests and having the opportunity to find different solutions for the same problem and learning from their mistakes, as not all hypotheses tested were correct and, with theoretical grounds, the students were able to refine their own experiments.

Now considering the technical aspects of the discipline Analog Electronics, the traditional theoretical test results were compared to the results obtained by previous courses offered. Qualitatively, the knowledge presented by students in the PBL methodology was greater than the knowledge presented by students from previous courses offered. Quantitatively, it is very difficult to compare the technical aspects between the course in the traditional way and PBL. While the traditional way trains students to solve specific exercises PBL trained these students to find technical solutions for problems belonging to Analog Electronics, which is the closest to professional life.

The autonomous learning and group lecturing were hard to evaluate, which was expected (FABREGAT, 2009); however, gains related to students being more in control of their learning process and having more security and confidence about their ability to solve a technical issue are expected after the PBL methodology.

7 Future Work

7.1 PBL in Other Disciplines

Within the Unifei Itabira Campus Internal Innovation in Engineering Education Workshop, much was presented, discussed and suggested for the use of PBL in Analog Electronics. There was a consensus among the teachers that the success of PBL was due to the characteristics of the course, which has theoretical and practical activities that are fit for projects covering all the disciplines subjects. Thereby, a future work will be to plan other disciplines of electronics core from the courses of Computer Engineering, Control and Automation Engineering and Electrical Engineering.

The electronics core consists in the following disciplines: Analog Electronics I and II, Digital Electronics I and II, Analog Integrated Circuits and Digital Integrated Circuits.

Already in this semester, 2nd/2013, the discipline Analog Integrated Circuits, considered of great difficult with very low approval rates from the Computer Engineering course, is using PBL with the same characteristics present in this paper for Analog Electronics. The intermediate results regarding students' scores show a quantitative increase in students' grades, comparing with previous offerings. A detailed study will be conducted on the activities and outcomes of PBL in Analog Integrated Circuits.

The next step will be to use PBL in the Digital Electronics II course in the 1st semester/2014. The main goal is to implement PBL in all electronics core using multidisciplinary and interdisciplinary projects, similarly as proposed in (SAUER, LIMA & BOOTH, 2011) by the end of 2015. Other disciplines, outside the electronics core, as software engineering, programming language, data structure and databases are starting to adapt PBL into their course seeing that these classes also have theoretical and practical activities that can be guided by problems and projects.

7.2 Improvements in Analog Electronics PBL

As students do not have a large experience in team work, teachers will adopt in the next PBL offer an ice-breaking activity as proposed in (FARRERAS & BOFILL, 2011). This ice-breaking activity will not only be used to integrate students, but also to make them understand what brings success to a team work, by discussing what are the best practices and behaviors. This dynamics help students know the other members' opinion, identify and prevent possible problems.

8 Conclusion

After all the analysis and considerations, it is possible to answer the questions proposed by the teachers' reflection on the use of PBL in Analog Electronics, listed in the introduction. Taking into account the approval results, it is clear that PBL creates conditions for students to pass the course, absorbing the knowledge necessary.

Furthermore, examining in detail the replies on the Educational Process Evaluation Form, many students related about the integration of knowledge among Analog Electronics and other disciplines previously offered in the engineering course, especially Basic Electricity. This was an exciting and expected result, for the reason that the teachers had noted, in past classes, that students were unable to connect tools of Basic Electricity with Analog Electronics. At the end of the Analog Electronics' project they were capable of identifying and using concepts of Basic Electricity to support their activities in Analog Electronics.

Skills like oratory, writing techniques, presentations to small groups, reliability, ability to work in teams, scientific and technical research were, undoubtedly, developed by the students. Even though these activities were not performed all the time, at least at some point, students had the opportunity to do some of them.

Perhaps the greatest gain was in the practical activities. It was quite clear that students can elaborate their own simulations and experiments to test their technical hypotheses after researching Analog Electronics' theoretical concepts. The road map prevents students' ability to solve their own problems, since it does not allow the testing of new solution possibilities and, rarely, a road map presents a problem, just follow-up steps to get expected answers. The independence caused by the absence of a road map lead students to learn from their mistakes, questioning themselves and constructing their own reasoning, going according to the constructivism theory. Earnings related to this experience were reported by a group of students which won an innovation contest in the following semester (2nd/2013) using the concepts and development methodology learned in Analog Electronics.

Students' interest in the subject also increased, which can be concluded considering the very low dropout rate. Maybe the lack of evaluated activities provided students with many chances to be approved or the greater proximity to the subject by solving problems and testing solutions in laboratory; the fact is that students did not abandon the course during the semester.

Although students had not achieved a satisfactory result individually, according to the traditional method of evaluation, this result is not entirely negative. It indicates that students work better in groups, which is closer to his professional work environment and also a desirable characteristic by companies that will employ this worker.

The teachers involved acknowledge the fact that the traditional method of teaching and learning should not be extinguished, but active methods demonstrate a large qualitative gain in the process of teaching and learning and should be encouraged. Although, it is still difficult to convince other teachers to adopt active methods of teaching and learning such as PBL, the positive results like the ones presented in this work can motivate others to try new approaches and, so, cultivate a new culture of teaching and learning.

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Fast-track On-site Project Delivery: A Flow Based Approach to Learning

Rodrigo Pascual Jimenéz*, Pernille Hammar Andersson*

* Mining Engineering Department, Pontificia Universidad Católica de Chile,

+ LearningLab DTU, Technical University of Denmark

Email: rpascual@ing.puc.cl, pea@llab.dtu.dk

Abstract

This paper elaborates upon how flow theory paired with active learning methods and with a conscious attempt by the teacher to create a learning environment, which also takes into account the emotional aspects of learning and meta-cognitive processes to enhance student motivation and learning outcome. The hypothesis is that if flow can be created through the teaching activities in a university course, new possibilities emerge to support the students to discover their full potential as individuals and learners.

We present a case study that exploits flow theory in a fifth-year course in a mining engineering program centered on the delivery of a project developed inside a company in a very short time. A survey has been conducted among the students in the course where they have rated their experienced emotional states with respect to the flow. Interesting results indicates a profound and enduring impact on students learning specially in the active learning parts of the course.

Keywords - Flow in learning processes, Project cooperation with industry, Active learning to prepare for generic competences, Intrinsic motivation, Self-actualization

1 Introduction

In the community of Engineering Education there is an ongoing discussion how to develop education programmes and teaching activities to more efficient support student learning and the students' development of engineering competences. Through this discussion, organised in national and international networks like for example the CDIO initiative and Active learning in Engineering Education, a common understanding emerge that problem based learning methods and real engineering cases is one of the ways forward to develop Engineering Education to better prepare students for their professional work as engineers (Crawley et al. 2007). The question that follows is how to implement an active learning paradigm and how to sustain this development in Engineering Education. Important to support this development is the engagement from the management level for this development and also a developed understanding among the faculty that changes need to take place in study programmes and in courses to be able to attract skilled students to engineering education and to succeeding educate them to be able to fulfil their future tasks as engineers in a global and dynamic labour marked (Graham, 2011).

As the work continues with getting active learning methods implemented in Engineering Education and with getting faculty prepared to change their way of teaching, the development in the society and labour marked steaming on in a quick pace and new issues are added to the agenda. When universities still struggle to implement student focused teaching methods, innovation and entrepreneurship are claimed to be added to the curricula and demands that a more students get involved in those activities and develop innovative competences.

The use of active learning methods in teaching where students take are more actively involved in taking responsibility for their own learning and for results of projects is a necessary development to succeed with getting innovation and entrepreneurship an integrated part of Engineering Education. Another important prerequisite for teaching innovation and entrepreneurship are involvement of real life case in university teaching which learns the students work with complex, multi dimensional problems and the creation of value for users (OECD 2008). Self-efficacy need to be developed among the students and a self-awareness that they can contribute to improved or new solutions (Zhao et al. 2005).

The teacher's role in this setting becomes more diverse and includes more roles than being the expert in the subject but also being a supervisor and facilitator of a multitude of learning, social and personal processes.

At the same time as focus in teaching are including more and more perspectives, deep disciplinary knowledge is crucial for innovation and for highly qualified engineers. The consequences of this development is that the teaching in

Engineering Education must be effective on many levels and embrace learning of both general competence and deep disciplinary knowledge and also address the aspect of personal development among the students. How can this very complex multitude of aspects be unfold and integrated in teaching practise within the frames available?

One answer to this question is to broaden the perspective of teaching and learning in Engineering Education and in planning and designing of courses also include that learning is a process very much depended on feelings and affections (Turner, Meyer, Schweinle, 2003). If the "passion mode" can be turned on in the students and their intrinsic motivation towards the subject can be reached the students to be will be deeply involved in their own learning. Basically we want the students to flow while they learn which means that they are fully concentrated and can use all their personal knowledge and abilities to engage in studying and learning. Flow as a mental state have some prerequisites and if they can be used to create a flow based approach learning the students can be helped to learn in a deeper level and also learn some process skills which can help them to high performances also in other areas of their lives. The overall objective is to support the students to stretch their minds to come deeper into the subject and to come further in their learning. The assumption in this paper is that a flow based approach to learning can create a "fast-track-on-site project-delivery" (FTOSPD) and more efficiently help the students to develop a broader range of competences and disciplinary knowledge within the same time frame as a traditional course.

2 Flow as a state of mind

Flow is a mental state characterised by an experience of peak performance and total concentration when engaged in a task and as phenomenon it is mainly described within the paradigm of positive psychology. The concept is mainly used to understand how people experience quality in their everyday lives and to investigate strategies that can be used to live a more fully life and also how to balance your life to experience more joy and happiness in ordinary situations (Csíkszentmihályi, 1997, 2009). Studies imply that flow occurs when a person perceive clear goals and get immediate feedback just when it's needed when in a process of doing, performing or discover. The main prerequisite to enter a flow state in performance is an experienced balance between the levels of the challenge we are exposed to and the experience we have of our skills to meet this challenge. In order to obtain flow there must be a balance between the challenge and our skills that allows us to be totally focused on the task and have an experience of being in absolute focus and in control of the situation. All our psychic energy is directed towards the task and towards our performance. Thereby reduces feelings of worry and hesitation. Due to the high level of concentration there is no room in our consciousness for irrelevant and distracting thoughts. Working in flow state creates through concentration and motivation a sense of value and balance that is essentially worthwhile for the individual (Csíkszentmihályi, 1997, 2009).

A central concept in the theory of flow is psychic entropy. Psychic entropy can be described as feelings of boredom, worries and unproductive anxiety which consume mental energy and prevent us from using all our energy focused on a task or performance. In order to experience flow and in order to be able to perform at a high level, using all our resources and experience joy in our work we need to strive for reduction of psychic entropy. Joy in itself is also a driver for motivation which is a driver to be active and involve in tasks. The quality of our work and performances are also depended on our feelings, positive or negative, towards the task and the situation in which the task is situated (Csíkszentmihályi, 1997, 2009). It's important to be aware that entropy in itself is a neutral and the means to reduce it is not loaded if either positive or negative intension only with what specifically is the motivation for individual person. The reduction of individual entropy most always become balanced towards the consequences of the action for others. In order to fulfil its purpose to create flow and positive feelings, entropy need to be reduced on a more overall level and create value for greater purposes then solely for the individual. When this happens positive feedback is returned to the individual, which strengthen both motivation and the experience of flow.

Some individuals possess traits in their personalities that make it easier for them than others to enter a flow state of mind. In positive psychology those persons are studied in order to learn more about flow and the mechanisms behind it. They are described as autotelic personalities. Those individuals are to a very high extent self-directed and driven by intrinsic motivation. Everything they involve in has a value for them. Curiosity, persistence and low self-centeredness are also traits that are significant for a person which can be described as an autotelic personality (Csíkszentmihályi, 1997).

3 Flow as an aspect in learning

The traits that define flow as a mental state to help us focus and concentrate fully on a task and the way an experience of flow can create motivation towards a task resembles to a high extent with what is known as fundamental for enable deeper learning processes.

In order to be able to learn and give room for the construction of new knowledge and new abilities we need to be motivated towards the content or skills we are going to learn (Illeris, 2006; Biggs & Tang, 2011). In order to be an efficient learner we also need to reduce anxiety and we need to be able to direct our concentration towards the learning subject. Also direct feedback is crucial in a learning process (Illeris, 2006). Feedback contributes to our motivation and gives us the information we need to have the sense of being in control and to know in which direction to work. Also the importance of clear goals and the notion that they can be achieved and create satisfaction and helps our motivation resemble flow if the prerequisites for learning (Biggs & Tang, 2011).

In active learning methods those important fundamentals for a deep learning process are imbed and build on the work of many learning theorists as Dewey and Piaget (Kolb, 1984). One of the fundamentals in active learning is the Lewinian experiential learning model where the stages of concrete experience, observations and reflections, forming of abstract concepts and generalisations and finally testing implications of concepts in new situations form a loop which put the learner in the position of being self-directed and actively involved in its own learning process. The essential idea in the theory of experiential learning is that learning is a process where knowledge is created through a transformation of experiences which also is the fundamental idea in active learning methods (Kolb, 1984).

This fundamental idea in active learning and experiential learning results in the notion, that learning is a process and not only the results of the learning outcomes. Seeing learning as a process also implies the similarity between active learning and the mental state of flow. This opens for broader perspectives on teaching and learning leading further on the road away from the role of the teacher as merely someone who is presenting the subject content, towards a teacher role which also includes facilitating students' learning processes. Embracing this approach to learning the teacher role is broaden to also facilitate meta-cognitive processes that would lead to life-long learning, a key skill in a highly dynamic labour market. To acknowledge that learning is a complex mental process that also includes individual motivation and social interaction and which have other goals than just the transfer of subject knowledge, can help teachers develop methods to more efficiently enhance learning among their students (Illeris, 2009). Research implies the emotional aspect of learning might be the most central and maybe this aspect in to be much more in the focus of teachers in order to truly succeed to create a good learning environment where students can develop to their full potential and be motivated to learn and improve (Turner, Meyer, Schweinle, 2003).

Also the autotelic personality has many resemblances with how the behaviour of an ideal student is described and the expectations of the students in Higher Education. We want the students to be self-directed, intrinsic motivated, devoted and directed towards the subject the study. This is very similar how a student with a natural deep approach to learning acts according to the phenomenography theory of teaching and learning in Higher Education (Biggs & Tang, 2011).

In the paradigm of phenomenography the concepts of deep and surface approaches to learning is very central. Deep approach to learning helps the students to study in a way that leads to more effective construction of knowledge and thereby better quality in the learning results than surface approach to learning. According to this theory the students adopted a surface or deep approach to learning in accordance with the teaching and learning context they exposed to. The consequence of this, a bit simplified, is that teachers more or less create their own students by the teaching activities they use and the learning context they (Bowden & Marton, 1990).

If a teacher can create a learning context which helps the students to be in a position where they have they likeliness to experience flow and thereby learn a way of working that can help the to perform better using what is known about flow theory and what in general enhance learning and how those theories gripe into each other much would be won in education to help the students perform at their peak level, and through motivation enhance their study results. The bearing idea in the case study described and investigated in this paper is that active learning is the main method to reach those objectives and to create flow among students in learning.

4 Case study

Our case study corresponds to a mandatory course of the fifth year of the mining Engineering program at Pontificia Universidad Católica de Chile. The university can be classified as a medium-size (~20000 undergraduate students and ~5000 graduate students), research-oriented University. It ranks 2nd in Latin America in the 2013 QS ranking (QS 2013). The course has been used previously in other references (Pascual, 2010; Pascual & Scheele, 2011; Pascual & Andersson, 2012) to test other active learning tools and strategies. In this paper we focus on what we have denominated "fast-track-on-site project-delivery" (FTOSPD) and the focus is on facilitating the students to achieve flow to enhance their learning processes and to give them an opportunity to learn some strategies to handle also other situations in life. The main teaching activity in the course is an on-site industry project. A project of this kind has

been shown to enhance intrinsic motivation and meaning creation to the students, who are protagonists of their own learning (Pascual & Andersson, 2012). Flow is used to increase creativity in an open-ended challenge project. The project is fully developed during a one-week immersion in an actual mining site. Such a setting implies a high challenge for students who must show different kinds of skills in order to achieve intended deliverables. The process is highly social and exploits concepts from peripheral learning (Wenger, 1998, Lave & Wenger, 1991). The hypothesis in this work is that if all the traits that lead to flow can be set to place through the teaching activities in an Engineering Education course, there might emerge new possibilities to support the students to discover and show their full potential as individuals and as learners. The overall goal is to support the students to stretch their minds to come deeper into the subject and to come further in their learning. Before describing FTOSPD we present briefly the context in which it occurs. Then we justify the use of FTOSPD and how it promotes Flow based learning in our students. Initial evidence of success is then presented.

4.1 Course context

Following ABET accreditation, the general program of the Engineering school shifted to a competence-centered one in 2009. In 2013 a new shift to enhanced curriculum flexibility was implemented. With the current curriculum, after 2 years of compulsory courses, students may select a major (10 courses) and a minor (5 courses). The expectancy of the school is that after this program, the four-year bachelors will be able to enter the labour market and that they will continue to a master program or return after gaining some experience to gain the engineering degree. This bid to a more flexible curriculum may affect positively the level of motivation of students to achieve practical skills that they will need as soon as they enter to work. In that direction, majors (and courses) offering opportunities to apply theory in real disciplinary settings may have high student demand, and substantially increase student employability.

Chilean engineering programs include at least two one-month or two-month summer internships embedded. The first one usually implies basic work, while during the second a more developed set of engineering tasks is desired. Usually there is a follow up by one engineer and no follow up by any academic or fellow student(s). The learning power of internships is a lottery. It depends a lot on the culture of the company and the support of the supervising engineer.

A second common practice in our setting is the industrial visit. Usually it is a full day experience where students observe (in general for the first time) industrial processes and pieces of equipment. The visit is usually guided by the academic of the course responsible for that visit and has a focus on the topics covered by that course. No deliverable is usually asked from the students.

The new curricula offers an introductory design course during the first year intended to develop creativity and add significance to the compulsory courses in basic sciences that are located in the first two years. Four years separate this interesting learning experience to this senior course.

Based on the concepts of internships and visits, but also considering the beneficial effects of creative challenges, and active, project-oriented, flow-inducing, collaborative-work experiences, we implemented the FTPD since the spring 2012. It consists on sending several small groups of students to a mine system (which usually comprises the mine itself, the processing plant(s) and the port installations (Figure 1)). The groups are displayed in several business units. At the end of the FTPD, each group must deliver a report and a presentation to senior management where they must describe: (i) the process of problems recognition, (ii) opportunities detection and selection, (iii) description of the proposed solution(s), and (iv) the associated business case(s). FTPD represents an important challenge not only for the students, but also for the professor. He must achieve attainment of high-level cognitive skills from his/her students in order to achieve acceptable/original solutions to selected problems. But the challenge also requires deep insight from the students in order to see problems and opportunities where insiders do not. This requirement has imposed new demands on the course as the students usually work with passive learning techniques, reducing their natural curiosity and insightful naivety. Such values have been recognized in process-improving strategies such as Lean thinking (Womack, 1996) and its well known problem-recognition tools, Gemba walks (Womack, 2011) and Value Stream Maps (Rother, 2003). As students lack professional experience, a strong collaborative effort is required, and for that, trust, mutual support and collective intelligence are assets that facilitate the achievement of meaningful results of the FTPD initiative. In order to facilitate the use of these attitudes and skills, several outdoor team building activities are programmed during the term. Figure 2 shows a time line with a typical course configuration and Figure 3, some evidence regarding the outdoor team building activities during the autumn 2013 semester. Figure 4 reports evidence from the on-site immersion itself.



Figure 1. Typical mine system infrastructure (mine, plant & port respectively)

Week	1	2	3	4	5	6	7	8	9
	Introduction	Risk analysis	Opportunity maps	Reliability analysis	Maintenance optimization	Interrogation 1/4	Inspections optimization	Spares opt.	Spares opt.
	Communication skills	Communication skills	Outdoors team building 1/3	Value stream maps				Outdoors team building 2/3	Team home work delivery
Week	10	11	12	13	14	15	16	17	18
	Interrogation 2/4	Redundancy analysis	Immersion week	Equipment replacement	Contract management	Interrogation 3/4	Public seminar		Interrogation 4/4
		Troughput analysis		In-site project defense			Outdoors team building 2/3		

Figure 2. Time line of the course during the 18 week semester.



Figure 3. Some outdoor team building activities during the spring term 2013.



Figure 4. Students during the immersion week spring term 2013.

4.2 Survey on students learning experiences

A survey has been used in the course which is constructed in the same way as the Experience Sampling Method traditionally used to measure flow state (Csíkszentmihályi 1997). In the survey the students are asked to rate their experiences of the different teaching methods used in the course in accordance to the trait that signifies a flow experience. The teaching methods included in the survey was lectures, exercises, laboratory work and workshops on LEAN management, wiki-collaborative group work and oral communication, the industry challenge which included work in the mission-control room and at last the international conference with industry representatives and experts in the field of subject where the students presented the results of their projects.

The instruction to the students in the survey was:

- During the course you have been through some different teaching activities.

- Please look back on the course and recall your experiences from the different activities and rate them regarding to the following aspects.
- On the scale you use 1 as your lowest score and 7 as your highest.
- For example if you felt very happy during a course activity you put a cross at 7, if you felt moderately happy you put a cross at 4 and if you felt very unhappy you put cross at 1.
- Please also rate how challenged you experienced the different activities and how you judge your skills to perform well during the different activities.

The students were to rate on a Likert scale ranges from 1 to 7 how they felt during the different teaching activities with respect to being feeling happy, concentrated, motivated, how great the challenge was to them and how they judged their skills to perform well during the specific activity. As a supplement to the rating of feelings towards the different teaching activities and to unfold some off the experiences behind their ratings the students were asked to mention the three most important things they learned from the course and in on words to describe what in the course that valued most to support their learning.

4.3 Results

Figure 5 shows the results of the survey made to the students during the first semester of 2013.

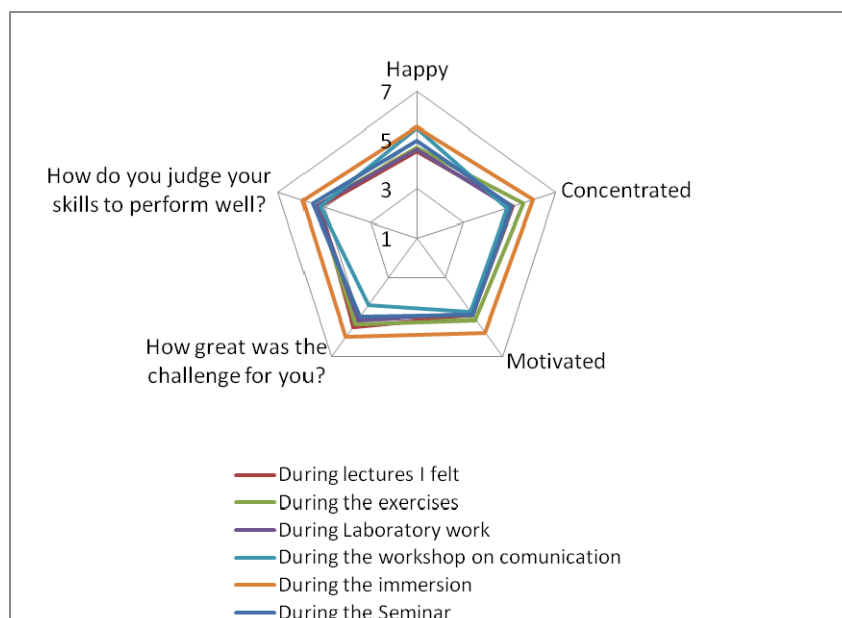


Figure 5. Autumn 2013 students survey

We observe how the immersion shows the highest values in all five dimensions in the study. It requires high levels of concentration from the students and the intrinsic motivation is clearly achieved. The results of the survey indicates that active learning methods support the traits that leads to a flow experience and which can help the students enhance their learning. There are also specific aspects of the industry challenge in this course that also can be found as something significant to flow according to the theory. It is an on-site project where the students interact directly with industry and it is one of primer driver for learning and has a positive impact on the motivation of the students (Pascual & Andersson 2012). Due to flow theory motivation towards the task is crucial. That the result of the students work is of uses for others, in this case the mining companies can be related to the experience of reduction entropy which is very central in flow and very goal of flow as a mental state. Also the feedback which loop back to the students can strengthen their experience of flow by making them know that the result of their work is good and satisfying, and if not they can while being motivated towards the task take actions to get a better results. The intense feedback loops in the industry challenge pair with that the students are working with real cases which are meaningful for them, and the industry, is important to strengthen a flow experience, and likewise learning.

Table 1 presents an outlook of the survey made to the students by the school of engineering. In general, students are satisfied with the course, except in the teaching organization dimension. An explanation for this is that FTOSPD requires a lot of personal work and flexibility in front of open-ended problems that must also be identified by them. FTOSPD force students to think out of the box and out their comfort zones where they are used to be. They complain regarding the amount of work that this approach requires. But they also recognize the learning power of the initiative.

During this course, (Workshop or laboratory), how often the teacher ...	In several or most of the classes
...used bibliography or resources (of information, audiovisual, artistic or others) varied and relevant to the course objectives?	93%
... linked the course contents to examples associated to real or hypothetical situations?	94%
...presented new ideas, findings or methodologies associated to the contents of the course?	87%
Regarding the teaching organization of this course...	
Time dedicated to the different activities of this course were adequate	40%
There was a clear relationship between the contents and pedagogical activities during the course	66%
The development and sequence of the classes, workshops and laboratories were clear and useful for my learning	67%
During this course, how frequently did the teacher encouraged...	
... the students to make questions during classes?	86%
...the students to look for information or do autonomous research?	67%
...the students to work in groups during any activity in or outside the classroom?	94%
During this course, How frequently did the teacher...	
...evaluated the students with criteria known by everyone?	73%
...delivered feedback on time (individual or group wise) about the strengths and weaknesses of the student's performance.	67%
...used different methods, situations, ways or kinds of questions to assess the learning?	87%
Overall	Expected of far more than expected
How much did you learn during this course?	80%
This course promoted my creative, analytic or critical thinking	74%

Table 1. School students survey outlook autumn semester 2013.

5 Conclusions

The hypothesis in this case study and try-out is that active learning methods can be used in order to create a flow state of mind among the student to enhance their learning. An important part in this idea trying to develop flow is that teacher to also need to include the emotional dimension of learning in the course design.

A conclusion from this initial study where the experience of flow is measured among the students is that evidence is found that support the hypothesis. The students report that they experience a balance between their judgments of the skills they have to meet the challenges they are exposed to and how they experience the level of the challenge. This is perceived balance is the most important prerequisite to have a chance to enter a flow state of mind. The students also report in the survey that they are highly motivated, have a high level of concentration and are feeling happy when working on the on-site immersion project. This indicates that the students are working in flow mode. The students indicate that the feel of happy during the immersion can be an indication that their level of psychic entropy is low even if they work hard. Low entropy is one of the main objectives with trying to create flow in a learning situation though it helps the learning process. The on-site immersion shows in the questionnaire to a higher degree than of the other teaching methods to fulfil the prerequisites of flow.

Hence, from this case study the conclusion can be drawn from that a “fast-track-on-site project-delivery” (FTOSPD) and a flow-based approach to learning can be used to enhance learning in Engineering Education.

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Problem based learning methodology applied on teaching electronic products development

Rodrigo M A Almeida*, Rodrigo P Rodrigues*, José Alberto Ferreira Filho*, Egon Muller*

*Systems Engineering and Information Technology Institute, Itajubá Federal University, Minas Gerais, Brazil

Email: rodrigomax@unifei.edu.br, rprodigues@unifei.edu.br, jose.alb@unifei.edu.br, egon@unifei.edu.br

Abstract

In the Electronics Engineering course on Itajubá Federal University, a PBL approach was implemented along the course with two main objectives: avoid the course evasion and improve the students product development abilities. The project chosen was an electronic microprocessed product. Both the hardware and the software were developed with the co-design principle. The results obtained so far are motivating: no student dropped off the classes and the projects have a high development quality.

Keywords: problem based learning, co-design, printed circuit boards, product development.

Introduction

Development of a full working electronic product is time consuming and the process is not user friendly. The printed circuit boards (PCB) project demands a high level of decisions given the amount of design variables and options available. The software development may become another problem because, in general, it can only be started after the first prototype has its hardware fully functional.

These facts contribute to a slow development cycle for electronic devices with lots of unpredictable problems, becoming an unattractive task for students and even for electronic engineers.

Another problem faced by the developers is the amount and range of technical knowledge needed for one project. The person needs to know about digital, analog and power electronics to project the circuit.

Instrumentation is required to almost all sensor inputs, even if the developer only needs to select a sensor, as the amount of options, both commercially and technically, is huge. To comply with EMI/EMC requirements the developer needs a deep understanding on electromagnetism and layout techniques. Communication protocols are a common requirement for newer projects, both wired and wireless ones. In order to complete the development cycle, programming skills are fundamental, as most electronic projects nowadays use a microprocessor or a microcontroller. It is also not uncommon for the project to have requirements for real time tasks or extra security needs, as cryptography or external user validation.

To fully train an undergraduate student to be able to work on electronic products development is an intensive task that, due to the amount of knowledge needed, may become unattractive to the students. In order to motivate the students and to show the importance of all the topics on the electronic engineering course, a PBL approach was developed consisting of three classes on the 5th, 6th and 7th semesters. The student is required to build a fully working product prototype, both the hardware and the software. In order to reduce the evasion problem, one class on embedded programming is provided on the 1st year with a PBL approach, allowing the students to have their first contact with electronics development.

Among the Brazilian universities (Villas-Boas, 2012) this is one of the first initiatives to have a PBL approach inserted formally on the graduation curriculum, devoting three classes specifically for this purpose.

Motivation

It is a common practice in undergraduate engineering courses to concentrate a significant amount of theoretical subjects in the first two years of the course (Dym 2005). Depending on the approach taken during these subjects, the students may easily lose their motivation due to the apparent lack of applicability of all the initial theory taught. This approach, and its consequence loss of motivation, may be credited as one of the causes of undergraduate engineering student evasion (Filho, 2011) (Reis, 2012).

Haertel (2012) made a research on "what way universities contribute to educate creative engineers nowadays". The universities may sometimes overfill the students' time with theoretical classes giving no spare time to the student exercise his/her creativity with projects. This may be the cause for the industry feeling that students "lack of understanding and appreciation for design-oriented skills" (Lang 1999).

These facts lead to the two main objectives on using active learning techniques, specifically the problem based learning approach, on the electronic engineering course.

The first one is to reduce the course evasion. With dedicated PBL classes the student will have contact with a big project, in which he/she could make use of all the technical knowledge obtained so far. This will show importance of the other (non-PBL) classes on the course and how they are interconnected. The second one is to motivate the students to work on electronic products development following the technical career, instead of looking for administrative jobs.

Theoretical references

One effective way to pass knowledge in one field to the students is to make use of lectures (Bransford 2000). The biggest problem with this approach is that it is ineffective on what concern to transform the students new knowledge in useful and usable skills. Laboratory activities help the students to make this transition but it is not always effective mainly because the limited time available. The PBL methodology can help in this process. Miao (2013) states that "the reason PBL is successful is because PBL emphasizes meaning and understanding rather than rote learning and memorizing". This gives the student a feeling that the subject they are studying has a practical application. The active component on the learning improve the knowledge retention rates, that otherwise could be "very poor and as low as 5%".

The PBL approach also provides students with skills that will help them in their professional life as problem-solving ability, team skills, the adaptability to change, communication skills, self-directed learning and self-assessment skills (Woods 1994).

There are distinct approaches (Ribeiro 2004, Villas-Boas, 2012) when concerning the PBL methodology, but all of them presents a problem/project to the students who became, themselves, the focus of the learning process: they need to organize in teams trying to understand the proposed problem and find solutions with knowledge they have. If the knowledge is not available, they must make a plan on how to acquire it, share with the group and, with the new knowledge, propose the best solution among the options.

This process is exactly the same one used by engineers when developing new projects or products (Osborne, 1993). A common approach is to first define the scope: requirements, targets, features. If there is any knowledge that the team doesn't have, they try to acquire before the development phase. If any new problem is found on the development phase and the knowledge to solve it is not available, the engineer dedicate its time to find the answer. After the solution is found, it is explained to the team to avoid similar problems on the future.

Contextualization and the PBL approach

The Federal University of Itajubá is a 100-year institution located in the southeast of Minas Gerais, in Brazil. It have experienced an accelerated expansion over the last 5 years with a projection of 232% for graduation students (UNIFEI, 2008). The number of students entering each year raised from 525 in 2003 to 1265 in 2013, with an increase of over 240%.

The electronic engineering graduation started in 2009, having its first students to graduate planned for 2014. The whole course was planned to use a PBL approach. Although it is not feasible to imbue all classes with PBL, some key classes were idealized with this methodology in mind. This was done to avoid, or at least mitigate, the problems with course evasion.

The course evasion is a complex issue faced in almost all courses in the university. There was also a concern that it could be worse for the electronic engineering for two reasons: the recent started course, as the students tend to move to more established ones, and the new ingress method (ENEM) proposed by the government. The new method makes easier for a student to choose any university he/she wants because they only need to make one national test. The problem arise from the fact that, being an online tool with real time positioning feedback, the student may choose a course with a lower pass mark than the one he wants, making the students more prone to give up from the course.

In order to mitigate these problems some initiatives were taken: give the students an initial experience on electronic projects as early as possible, to motivate the students to stay on the course, and implement a project based learning (PBL) methodology along the whole graduation program as presented in the Figure 1. The first light blue represents the classes fully devoted to project development through the PBL approach. The second light blue is the graduation final project (GFP), where is expected that the student could use all the knowledge he/she acquired on the graduation to build a big project on his/her field of interest.

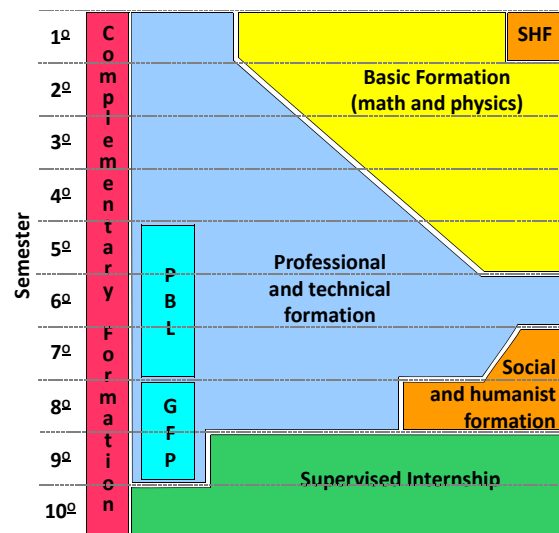


Figure 1 Electronic engineering course curriculum

In order to give the engineering student the contact with design techniques from their very first day, two courses from the first year were adapted to give the students their first contact with an electronic project. This made possible to start their professional formation as they enter in the graduation, avoiding the lack of motivation as noted by Filho(2011) and Reis(2012).

In these classes it is used an electronic development board to teach programming skills, while giving the students their first contact with electronic components. The board consists of a microprocessor controlling a LCD display (compatible with HD44780), a 4x4 keypad and capable of controlling a temperature using two PWM outputs to drive a heater and a fan. The temperature is read using a linear temperature sensor (LM35). The board is depicted in the Figure 2

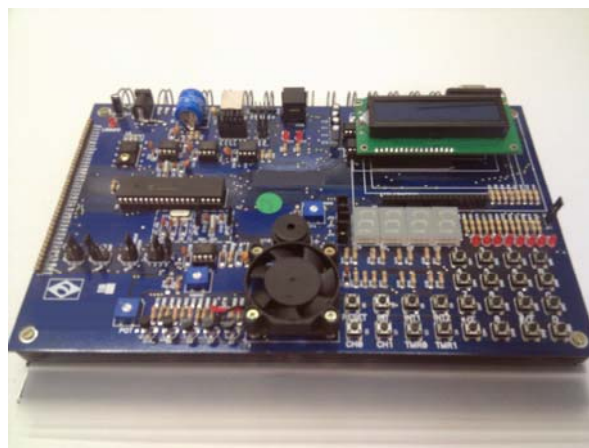


Figure 2: Development board used on the first professionalization course

The tools used in the course, both the electronic board and the software development environment, were chosen among the one's used by the industry. This way the students can have contact with software/firmware development and feel they are learning things that they are really going to use on their professional life. Although using didactic kits have its importance in the university in a multitude of scenarios, it is a good approach to give students a more real example to improve their motivation to keep their studies.

Another set of two classes are offered at the fifth and sixth semesters. These courses are fully implemented using the PBL methodology where the students are required to build a fully functional microprocessed electronic product in two semesters. Because the complexities of hardware and software development, a co-design approach is used. There is also a third fully PBL course on the seventh period. This class is also paired with a project manager course to provide the basis for the students graduation final project (GFP) on the eighth and ninth semesters.

The first concept presented in PBL 1 and PBL 2 courses is the electronic product itself. Then the features that will be present on the product are discussed, the requirements are defined and the main objectives for the two semesters course are presented. This way the students have a whole view of the development process

and have an early visualization of the product they will develop.

The biggest motivation to the students is to be able to use the same tools available in the market, having their boards manufactured in a commercial process, to choose any of-the-shelf component and have their first product developed by themselves.

This way the student is wrapped in a real development atmosphere with dedicate rooms to develop, assembly and test their products. The students are free to make their own choices and to choose their team. There are only five deadlines set in order to keep with the board production and academic schedule: 1) Schematic and layout definition, 2) Gerber and bill of materials generation, 3) Board assembly and electronic testing, 4) Software testing 5) Application development. It is expected to have all boards fully functional at most at the third phase.

PBL 1 – Hardware development

The first full PBL class was designed to give the students their first contact with a full electronic project, from the circuit conception to the board manufacture and assembly. The main goal of the class is the development of a general purpose electronic development board which had a subset of the features of the board used on the first technical course (Figure 2). The subset was chosen in order to use the students previous knowledge as both a motivation tool and a speed increase on the project development. The board will be used in a subsequent course (PBL 2).

The students were required to form groups of three members and to start the project according to an initial set of features. This set of features was requested as basic operation, debugging and interface behavior have a common point and that the students could use the board on the second course. No other requirement was made. The students were free to elaborate the layout, both component placement and routing, and incorporate any additional features they want as long as they keep the proposed budget restriction. The Table 1 enumerates the set of given requirements and features.

Table 1: Requirements and features for the development board

Item	Description
1	Employment of the PIC18F4550 in SMD package as the microcontroller unit
2	Employment of a reset button
3	Compatible to a Pickit 3 programmer/debugger
4	Employment of a LM35 temperature transducer
5	Employment of a LDR light transducer
6	Employment of a group of at least 4 LED's
7	Employment of a 4-button keyboard
8	Employment of a 16x2 LCD
9	Employment of expansion header for unused pins

Aside being extremely complicated, the electronic product development can be easily divided in steps. Each subsequent step requires that the previous one to be finished and correct. In order to help the students to be able to develop all the steps correctly, the course was divided in two main groups of activities: guidance and development activities.

Guidance activities were used to present topics related to each key step on the product development: schematic capture, PCB routing and footprint development, co-design simulation, component selection, bill of materials generation, generation of production files, assembling and testing. During these activities, some key concepts and examples were presented. These activities were designed to be as short as possible to leave time to the students project.

Development activities were interleaved to the guiding ones, so the students could develop parts of the project while producing intermediate results. In this way the first PBL class can be thought as a collection of mini-projects that are linked in a linear fashion. This way, the intermediate results can be used as point of analysis by the instructor, ensuring that the projects will be developed correctly.

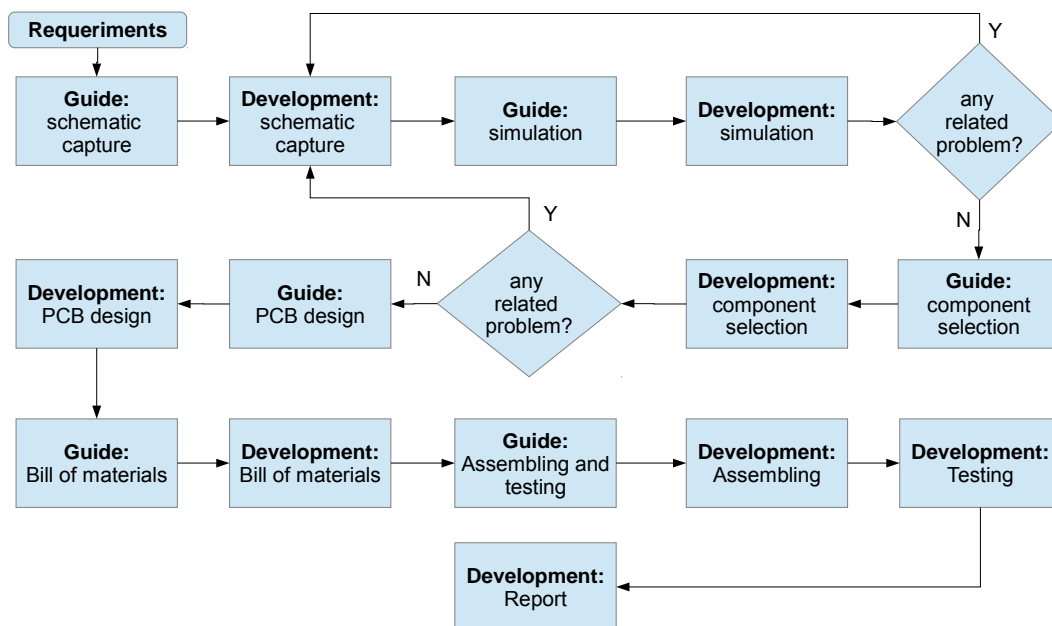
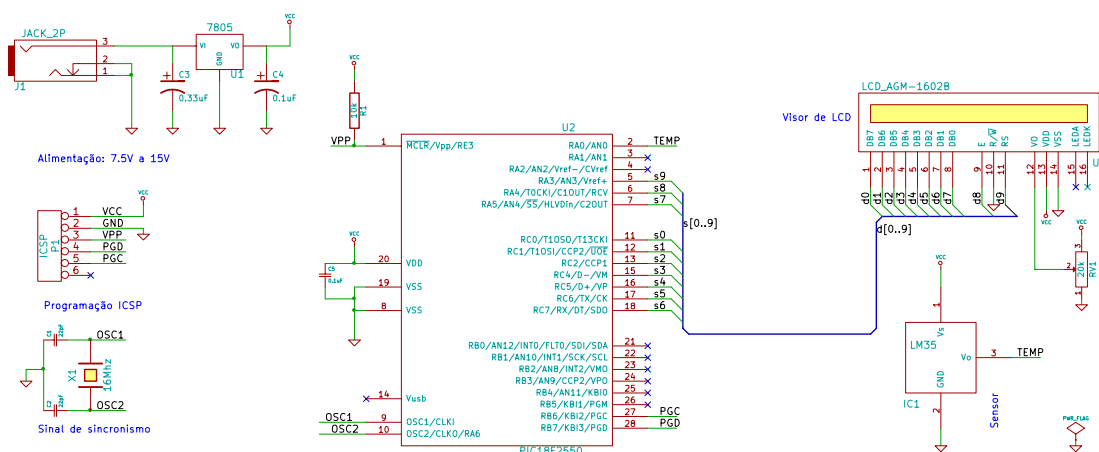


Figure 3 depicts the mixing of guidance and development activities and the flow adopted during the course. As it may be noted, each of the main topics related to the development of electronic devices are handled by a pair of guiding and practical development activities. It is worth note that all the practical design activities, except for the simulation, where developed with the use of an open source electronic design automation (EDA) tool called *KiCad*. The simulation practice was based on *Proteus Virtual System Modeling*. This tool make it possible co-simulate microcontroller code in the same context of mixed-mode SPICE circuits. The addition of this feature among the others was devoted specially to demonstrate the students how software and hardware characteristics may influence each other.



During the initial guiding activities, a reference board is designed so the students become familiar to the EDA tool selected. Figure 4 shows the reference circuit presented to the students.

With the results of the PCB design activity validated, the production files (gerbers) were sent to a professional PCB house for production. The electronics components chosen by the students were bought based on the generated bill of materials. With both the components and the manufactured PCB boards in hand, the students assembled and tested their development boards. As the last development activity, each group produced a final reported. This report describe all the practical activities developed, the technical results attained and the associated difficulties found during the development.

PBL 2 – Firmware development

The second PBL class was devoted to the firmware development. It was divided in two parts. In the first one the students were required to build an autotest tool that could help in the production line to test the products. This routine, aside its own advantages, is a good starting point for the students to debug the hardware issues, as it will be the first time the students could program their board. In the next step the

students are required to build a fully configurable alarm station accepting commands from the both the physical interface and the serial communication line.

The autotest routine must require the user to press each button in sequence to test the inputs. The messages should be printed in the LCD display. After each successful input one indicative LED will light. After all inputs are tested the two sensors values must be shown in the LCD until the board is reseted. It is also common to leave this routine in the final product accessed through a special code to help the maintenance to troubleshoot any hardware problem. The Figure 3 presents the proposed routine to the students.

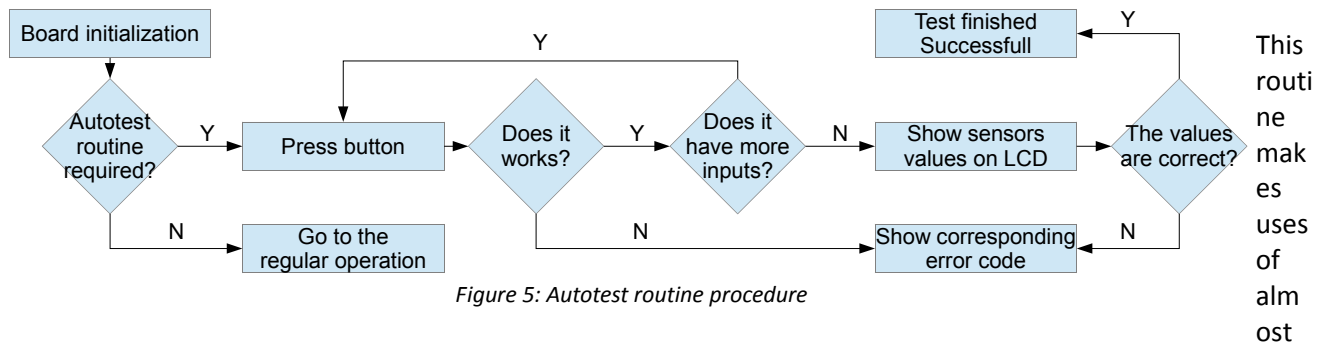


Figure 5: Autotest routine procedure

all peripherals on the board. The students are oriented to develop each peripheral as a separated driver, thus making the development of the application easier in the next step.

To the product application development, there were made some requirements for the students:

1. The two sensors, both light and temperature ones, must have a high and low level alarm, each of the four must be configurable;
2. The alarm check frequency must be configurable;
3. The board must accept commands from both the physical input and the serial communication;
4. The board must show the sensors current value while on normal operation;
5. To enter in the autotest routine a code should be accepted only in the first 2 seconds, otherwise it can't be accessed anymore if the board is not reseted;

The students were free to implement any other feature on the board. They were told that each extra feature will count in the grades. This was done to motivate the students creativity and create a competitive feeling, as the grading will be relative to the best project.

Available environments for the students

In order to allow the students to build their electronic product two spaces were provided: one for hardware assembly/testing and the other for software development.

The hardware laboratory was made available to the students in a 24/7 policy. They organized themselves to use the lab tools. There were provided two workbenches with oscilloscopes, variable voltage sources, multimeter, a solder station, protection gear (smoke exhaust, anti-static bracelet, etc) and a complete set of pliers and screwdrivers.

In order to help them with the SMD (surface mounted devices) assembly, a trained electronic technician was available throughout the week. He also helped troubleshooting some of the problems the students faced.



*Figure 6: Electronic soldering station available 24/7 for the students projects.
All the tools and safety devices were provided.*

The software laboratory was made available only three hours each week for a formal attendance of the projects. In this time the students show their progress and the next steps are discussed. All the software were installed on the students laptops, allowing them to keep the progress anytime. This was possible mostly by using of only open source tools.



Figure 7: Computer laboratory with all the software tools, CAD, Simulators, Compilers and IDE, installed

The programming tool used was a PicKit3 debugger provided by Microchip through its Academic Partner Program. Ten kits were donated in 2011 and were used both in the PBL courses and some students extra researches.

Results

In the first run (Aug/11-Jun/12), four groups were formed. All the boards needed some layout changes. Two groups finished the system with all features implemented and two have problems with the sensors devices. In the second run (Feb/13-Dec/13), ten groups were formed. Two of the boards prototypes became fully functional in the first try, without any modification, neither in hardware or software. Considering that the software used in this first test was the developed concurrently with the hardware by using the co-design approach and tested only with the simulator tool, this is a great achievement for third year students with no

prior experience with product design.

The remaining boards had minor layout problems but all of them could be easily corrected. Some of the finished boards are presented in the Figure 5.

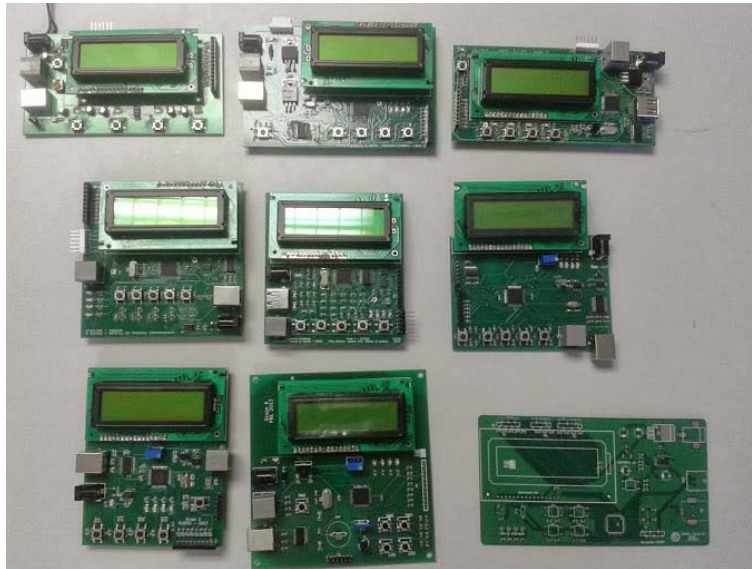


Figure 8: Electronic products developed, the students were given liberty regarding layout, placement and components decisions.

The most errors were noted to serve as guidelines for the future runs. The common ones could be grouped into the following sets:

- Footprint mismatch (mostly regarding VCC / GND exchange)
- Lack of connection between components (routing problem)
- Component operation failure (mostly because bad soldering skills)

The software course was still running at the time this paper was written but the results obtained so far were also impressive.

It was required that the students build a software capable of:

- Running an autotest to certify the hardware capabilities
- Fire a high level and a low level alarm for the two sensors (temperature and luminosity)
- Allow the user to configure the four alarms using the keys and the LCD or the serial communication
- Show, on a configurable time base, the sensor values on both the LCD and the serial communication

The autotest routine required that each of the hardware features to be tested: the LCD, the keys, the LED's and both the sensors. The test could use user inputs if it was properly explained using LCD messages. The Figure 6 presents one of the boards showing a successful autotest showing "*Teste concluido*", test finished.

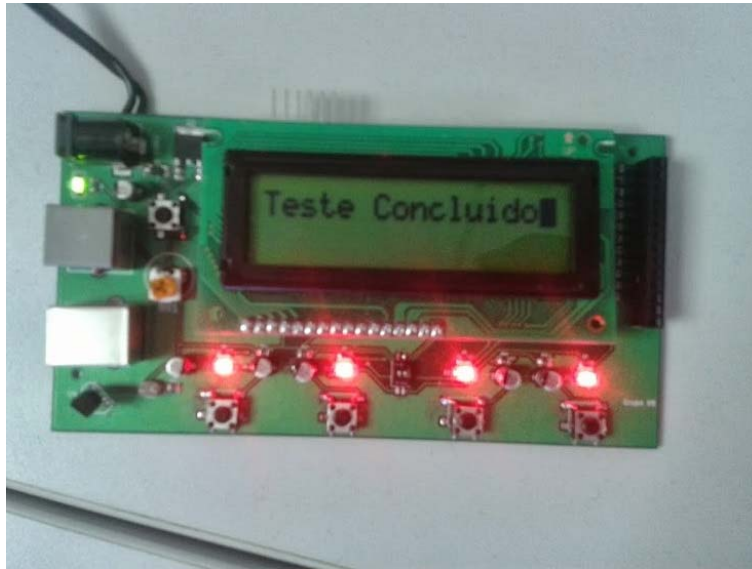


Figure 9: Board with firmware programmed and showing successful autotest

Regarding the students motivation the results were impressive. Even though it's hard to establish a metric to measure it, it's evident the increase of students interest in these classes when compared to non PBL ones. For both the runs already done, no student drop off the course.

In order to measure the outcomes of the PBL methodology on the students a survey was made. The survey consisted of 9 sentences which the student must say if he or she: completely agree (5), agree (4), is indifferent (3) disagree (2) or completely disagree (1) from each affirmative.

The sentences were:

2. The class methodology (PBL) is better than the traditional methods
3. I'd like to have one PBL class every semester from the course
4. The project developed is interesting
5. This class helped me to better understand the necessity of the other classes from the course curriculum
6. The other classes I took helped me in the project development (Consider all classes: math, physics and technical)
7. My formation as engineer will be better because I took these classes
8. The PBL classes were decisive for my stay in the electronic engineering graduation
9. I was willing to leave the course until I took the PBL classes
10. The ELT024 course (first technical course) and the PBL courses make me look forward to work as an electronic device developer/engineer

The nine sentences can be grouped in three groups of three sentences. The first group (sentences 1,2 and 3), is concerned on how much the students liked to be on a class with the PBL methodology. The second group (sentences 4, 5 and 6) try to discover the impact that the PBL classes take on the course flow and on the student's formation. The last group (sentences 7, 8 and 9) is aimed at how the PBL classes motivated the students to continue on the electronic engineering and how it helped to avoid the course evasion.

An open space was provided for the students to place suggestions, ideas or complains. 10 of the 19 students who answered the questionnaire wrote something. Only 5 commentaries have any complains, but even them pointed good impressions on the classes.

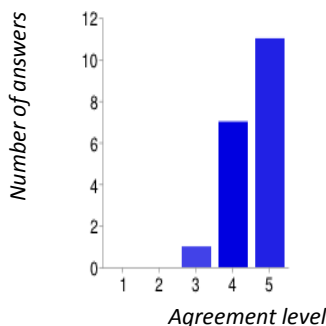
- "I can better understand an electronic board inner workings and it is easier to assimilate the important concept, even the hardware ones"
- "I think the class is excellent, the best class in the course that allows the student to have a very, a really very good experience in project development, in my opinion all engineering courses should have a similar class"
- "PBL classes certainly opened my eyes for a better understanding on how an electronic project works"
- "When people see that I made a controlled source on my 1st semester, programmed an electronic development board on the 2nd semester, and the PBL project, they become impressed with the course"
- "Regarding the PBL, I only think that the grading methodology wasn't explained very well, but the class subject is really interesting and the course should have one since its beginning, because it leads us to act more on ourselves, making a project

of this magnitude had its biggest difficulty on learning on how to organize ourselves, so having this since the beginning would make the course better”

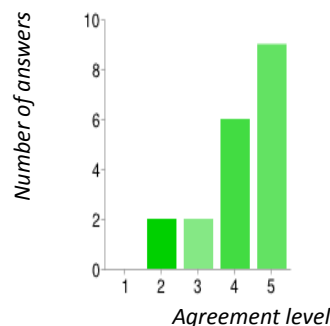
- “I think the first part wasn't well directed in the beginning, generating some doubts”
- “The teaching methodology is good, build the board is surreal... and see it working is beautiful. But I don't think the teaching methodology was very efficient, I think the professors should check the progress periodically, I also think that the professor should give a bigger support to the students and not only leave the responsibility of the project on our hands”
- “The only problem on the PBL classes is that they demand to many time, that may reduce the students productivity on the other subjects.”
- “The PBL classes should have the groups divided at most with 2 people, this would force the students to work more, and consequently to learn more.”
- “I think that it would be nice that on the next year we had another PBL class so the students could develop another electronic board from the zero, enabling them to avoid the mistakes done on the first course, this may lead to a develop of a more sophisticated or even commercially viable product. This could also be used as GFP.”

The Graphics 1, 2 and 3 presents the results from the first group of affirmatives, regarding how the students felt on being on a PBL methodology class.

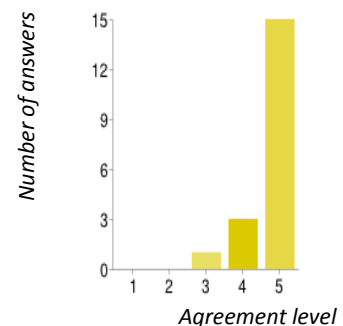
Graphic 1: The class methodology (PBL) is better than the traditional methods



Graphic 2: I'd like to have one PBL class every semester from the course



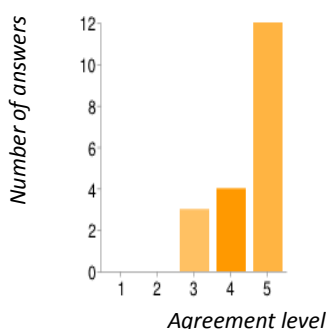
Graphic 3: The project developed is interesting



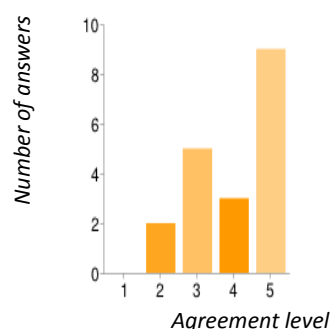
Although almost everyone (94%) liked the class, with the same number of people finding the project developed an interesting one. Besides this, two students answered that they don't want to have a PBL class on every semester. This may be due the amount of time required on the project development.

The Graphics 4, 5 and 6 presents the findings from the second group of affirmatives, related on the impact the PBL classes had on the students formation and how impressions on the course classes have changed.

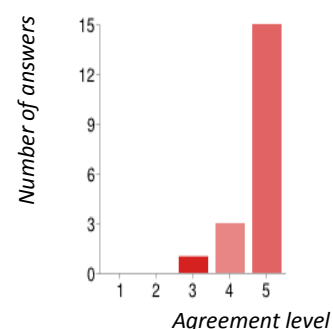
Graphic 4: This class helped me to better understand the necessity of the other classes from the course curriculum



Graphic 5: The other classes I took helped me in the project development (Consider all classes: math, physics and technical)



Graphic 6: My formation as engineer will be better because I took these classes

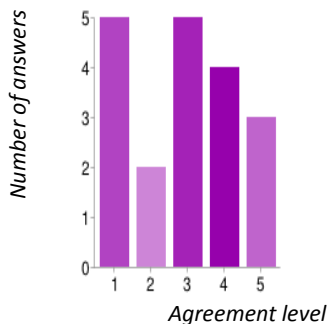


On regarding the PBL classes impact to the student formation, it can be seen that the classes have helped to improve the motivation of the student on realizing the importance of all disciplines on the curriculum. On regarding on the importance of disciplines, the majority (58%) found the disciplines in the course helped them in the project. Only 10% disagree with this affirmative.

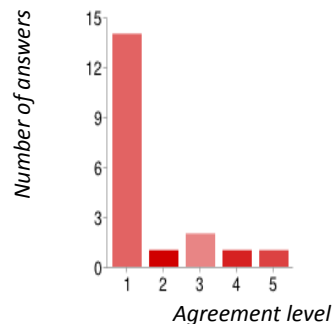
On what concern their impression if this class would helped them in their engineering formation only 1 student was indifferent and there was no negative answer.

The Graphics 7, 8 and 9 presents the findings from the third group of affirmatives, aimed on finding the impact that the PBL classes made on the students motivation towards their graduation on electronic engineering.

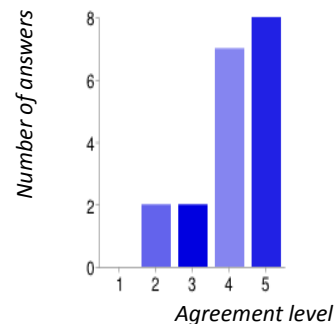
Graphic 7: The PBL classes were decisive for my stay in the electronic engineering graduation



Graphic 8: I was willing to leave the course until I took the PBL classes



Graphic 9: The ELT024 and PBL courses make me look forward to work as an electronic device developer/engineer



On the sentences targeted to investigate how the PBL helped to reduce the course evasion the results were very good. Almost 36% agreed that the PBL were decisive for them to stay in the electronic course. And two students was willing to leave the course until they took the class. Another good impact is a good number of students (78%) wants to work as an electronic product developer.

Conclusion

The two main objectives were met. At least two students that were willing to leave the course changed their mind after the PBL classes. Another group of students, almost 36%, devoted their stay on the course on the PBL classes.

The second objective, to motivate the students to work on more technical jobs, was attained with 78% of positive answers to the electronic product developer career.

Another good result found so far is that the project helped the students to better understand the course curriculum and the importance of all disciplines in their formation. It is good to create the culture in the university and motivate the students to engage in mathematics and physics classes.

The development level attained by the students is remarkable. With 20% of the prototypes having its hardware and firmware working without any modification on the first run is a quality level not easily achieved. Although minor corrections all products became fully functional.

The software results were not integrally available, as the classes was still in course, but most of the boards had their firmware programming finished.

The results observed were really impressive. This lead the university directors to create two new dedicate laboratories to PBL classes, one with all electronic tools and the other for software development. These laboratories will be available 24/7 to students have access to all necessary tools any time they need. This increase will accommodate future expansions on PBL on the other university courses.

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Didactic engineering for conceptual change in students' equilibrium and stability understanding

Michaël Canu*, Mauricio Duque**

*LDAR, université Paris Diderot Paris 7, Paris, France/GIAP, Universidad de Los Andes, Bogotá, Colombia

**GIAP, Universidad de Los Andes, Bogotá, Colombia

Email: m.canu134@uniandes.edu.co, maduque@uniandes.edu.co

Abstract

We propose here an example of innovative teaching experiment that promotes students' conceptual change (Posner et al., 1982). Our approach involves educational inquiry in order to identify students' misconceptions as well as a didactic engineering (Artigue, 1996) base on the Camps Conceptual framework (Vergnaud, 1978).

The core of the proposed session is a study of several 'simple' systems. Those systems are chosen for their apparent simplicity in order to engage students (and participants) in reflection and allow us to use one of the alternative conceptions (also called misconceptions) identified in previous studies. For each concepts (equilibrium first and then stability) they alternate individual prevision/definition phase and group definition phase in order to facilitate the emergence of cognitive and socio cognitive conflicts.

This approach allows to highlight a rationale based on the difference between initial and final configurations of various mechanical systems (Canu et al., 2013). This kind of rationale is a direct easy-to-use translation of the mathematics definition of stability proposed by Lyapunov that can be found only in mathematics language in control courses. Moreover, this kind of rationale is more general and more independent of disciplines.

Indeed, engineering students on control courses lack of an understanding of equilibrium and stability which are crucial concepts in this discipline. The introduction of these concepts is generally based on the study of "classical" examples from Newtonian mechanics enriched by a control system.

Throughout the engineering syllabus, equilibrium and stability are approached in different ways, at different academic stages: at early stages in essentially static ways, in mechanics for example, and later, by dynamical analysis, in control courses. There is little clarification of the differences between those ways and how the underlying concepts are linked. We assume that it is a major source of confusion and misunderstanding (misconceptions) for engineering students. Moreover, this same words are used in everyday-life with a meaning that no coincide with the scientific meaning and this could reinforce the confusion in the students' mind.

Several studies have shown that students encounter difficulties in understanding simple familiar or academic static cases from mechanics (Newcomer et al., 2008; Ortiz et al., 2005, Palmer, 2001). Some others shown that the understanding of equilibrium and stability is strongly disturbed when the studied systems are placed, for example, either in inertial or non-inertial moving reference frames (Tamayo et al., 2012; Canu et al. 2012). More generally, one can notice that students lack of comprehension about those concepts, even if they know the criteria and formulae of the discipline.

In fact, few of students' problems seem to be linked directly to a lack of knowledge concerning the mechanical concepts of equilibrium and stability but results from an inappropriate reasoning. While many classical engineering control courses are focused on declarative and procedural knowledge they cannot improve students' understanding of many situations because this implies strategic skills or reasoning like the one we propose in this study.

This example of hands-on session shows that one could take advantage of well-chosen situations in order to improve the engineering students' understanding of equilibrium and stability concepts.

Keywords – didactic engineering, equilibrium, stability, conceptual change, students' way of thinking, misconceptions.

1 Introduction

Engineering students on control courses lack of an understanding of equilibrium and stability which are crucial concepts in this discipline. The introduction of these concepts is generally based on the study of "classical" examples from Newtonian mechanics, as a pendulum, enriched by a control system (a motor which apply a torque on the axle of pendulum, for example, or a cart on which is mounted the pendulum). This approach supposes that the student manage those "classical" examples. But several studies have shown that students encounter difficulties in understanding simple familiar or academic static cases from mechanics (Newcomer et al., 2008; Ortiz et al., 2005, Palmer, 2001). Some others shown that the understanding of equilibrium and stability is strongly disturbed when the

studied systems are placed, for example, either in inertial or non-inertial moving reference frames (Tamayo et al., 2012; Canu et al. 2012).

More generally, one can notice that the students lack of comprehension about those concepts, even if they know the criteria and formulae of the discipline.

In fact, throughout the engineering syllabus, equilibrium and stability are approached in different ways, at different academic stages: at early stages in essentially static ways, in mechanics for example, and later, by dynamical analysis, in control courses. There is little clarification of the differences between those ways and how the underlying concepts are linked. We assume that it is a major source of confusion and misunderstanding (misconceptions) for engineering students. Moreover, those same words are used in everyday-life with a meaning that no coincides with the scientific meaning and this could reinforce the confusion in the students' mind.

2 Didactic engineering and conceptual change frameworks

Thus, this communication is focused on an innovative active learning classroom session based on the didactic engineering framework (Artigues, 1996). The aim of this activity is starting a conceptual change (Posner, 1982) in the students mind about those concepts. The model of this conceptual change which guides the activity is based on the Conceptual Camps Theory (Théorie des Champs Conceptuels, Vergnaud, 1978).

2.1 The conceptual change

The conceptual change theory (Posner, 1982) is based on the constructivism paradigm (Dewey, Ausubel et al.). Students do not come at school without ideas about scientific facts or explanations about nature phenomenon. More generally, they construct their knowledge in an active process that involves previous elements of knowledge they already have (schema) which can be either an academic knowledge or an experience-based one. From this perspective, students have to interact with the targeted knowledge in order to construct new links with previous knowledge. This process which aims at changing the student's cognitive organisation (the schemas) is called Conceptual Change (Posner, 1982). Moreover, the interactions do not limit to those with knowledge but in a social approach of the constructivism (Vigotsky, 1935; Doise, 1991), students also have to interact between themselves and with the teacher in the classrooms in order to reach this new organisation. In fact, those interactions involve a socio-cognitive conflict in the students which is a powerful lever of the conceptual change.

2.2 The conceptual Camps Theory

Vergnaud's theory about conceptual camps is a "cognitivist theory with aim at producing a coherent framework and some basics principles for the study of the development and the learning of complex skills, in particular for those from science and technology." (Vergnaud, 1990). The major hypothesis is that the acquisition of the meaning of a concept involves the student to strike with a problematical situation that contains the concept (or the related knowledge): Vergnaud talks about a "pragmatic development process" (*processus d'élaboration pragmatique* in French).

In this theory, one can define models and tools for describing processes and behavior of the student in front of a situation. One of those tools is the *scheme* (schème). It describes the invariant organisation of the behaviour of a person in a class of situations. It is a cognitive element that allows the operability of the subject's actions. It is composed of *operating invariants* (invariants opératoires), *action rules* (règles d'action) and *anticipation rules* (règles d'anticipation). Those elements possess their *application domain* – the set of situations where they can give an answer – and their *validity domain* – the set of situations where they give a correct answer (which is generally no empty).

From this perspective, an erroneous answer comes from the application of an action rule outside its validity domain.

2.3 The Didactic Engineering

This theoretical framework "refers to a set of classroom sequences designed, organized and structured in time in a coherent way by a teacher-engineer in order to conduct a learning project on a given content for a concrete set of student" (Artigue, 1998, p40).

The process which drive to this sequence is generally composed of four steps:

- a) A preliminary analysis stage which includes an epistemological, cognitive, didactical and pedagogical scope
- b) An *a priori* design and analysis stage

- c) The experimentation stage (the sequence)
- d) An *a posteriori* analysis and evaluation stage

This framework allows a measure of the impact of a didactical action by the confrontation between the *a priori* and the *a posteriori* analysis. The first contains some local hypothesis underlying by the targeted actions and the second is based on the data that comes from the effective realization of the sequence. This process allows a feedback from the real application of the sequence to the design of the sequence in order to improve its efficiency.

We are not detail all those stages but only give some significant elements of the a), b) and d) stages and describe the experiment.

3 The proposed didactic engineering

3.1 *A priori* design and analysis

Following the didactical engineering describe in the previous part one can resumed most of this first scopes in the figure 1.

This is a model of the targeted conceptual change that includes the following elements:

- On the upper plans: the conceptual nets (operating invariants). It is a representation of the links between the concepts in students' mind.
- On the lower plans: the prototypical situations with their limits and links (actions and previsions rules).
- Between upper and lower plans: the relations between the conceptions and the situations which produced them and in which we can infer the use of the rules (relational calculus)

The left part of the figure shows the starting state of the activity. It is a representation of the student behaviour in front of a given equilibrium situation based on our previous studies and the literature. In other words it represents the students' conceptions about those concepts. In a conceptual change point of view, the aim of the activity is to drive, or guide, students to reach the right state of the figure. This final state represents a conception of equilibrium and stability nearer to the scientific concept.

3.1.1 Equilibrium and stability definition

As shown in the right part of the figure, equilibrium concept is linked to stability concept. More precisely, stability is a characterisation of an equilibrium state. From a mathematical point of view, equilibrium is a stationary – i.e. time-independent – state for a set of equations that describes a system (Mathieu et al., 1991). In each application domain this mathematical definition can be traduced by a specific domain-dependant criterion (for example in Physics see Serway et al., 2000) while the direct translation of the mathematical definition can give a general *behavioural* criterion. In fact, it is sufficient to *observe* the behaviour of a given system in order to define its equilibrium state. This approach can be called "*a posteriori*" and our sequence is design for this kind of reasoning. On the contrary, a calculus-based criterion can be called an "*a priori*" criterion because it can be applied on the system before studying its evolution. Thus, from an "*a posteriori*" approach, we can define an equilibrium state as a state in which the system stay if no change occurs in the input of the system and in the absence of disturbances.

From the same point of view we can define an "*a priori*" approach for stability and an "*a posteriori*" one. The first one involves the use of a criterion applied on the system's data (as an energy-based criterion for example) and the second one implies an observation of the behaviour of the system. Thus, from an "*a posteriori*" approach, we can define a stable equilibrium state as a state in which the system tends to return, without any external actions, after a small and time-finite displacement of it. If the system does not return to its initial state after the displacement, it can be consider as unstable if it keep going away this state or indifferent if it stay in the new state (the state where the displacement putted it).

Because the "*a posteriori*" approach allows the processing of cross-domain situations, our proposed activity aim at developing it. Moreover, this approach which involved the observation of the behaviour a system is easily likable to the *prediction* of the behaviour of the system, in other word to the application of an "*a priori*" criterion which does not involved an observation of the behaviour of the system. In fact, as the observation of the system is not always possible, this methodology is essentially interesting from a teaching point of view.

The left side of the figure give a model of the correct student reasoning which is valid in all situations.

3.1.2 Common (mis)conceptions

Few studies have investigated specifically those concepts (see Canu et al. 2013 for a literature revision on this subject) in physics and all of them are focused on static equilibrium situations (Gunstone, 1987; Ortiz et al., 2005; Newcomer & Steif, 2008; Flores-García et al., 2010). In those cases students have difficulties in identifying forces acting on a system (for example, external or internal forces) in applying basics laws of mechanics (the net forces and net torques) and their rational depends on the configuration of the system in various cases. One can notice that both in the case of controlled systems and free dynamical systems, the conceptions about equilibrium and those about stability are generally mixed up by students (Canu et al., 2012, Tamayo et al. 2012).

The left side of the figure represent the common student conceptions about those concepts. One notices first that equilibrium and stability are linked but disjointed, as well as for equilibrium and instability. Moreover, immobility plays role in the conception of equilibrium and stability in particular in case of dynamical mechanical systems. Those representations imply the actions rules on the lower plan. We can notice that the separation between elements on the upper plan leads to (and generally comes from) a distinction, for the students, between classes of situations of equilibrium according to some appearance aspects. There is no link between classes of situation and thus exists some incoherence in the processing of situations. For example, the presence of movements like small oscillations of one system's variable can be a characteristic of an equilibrium state in the case of the human body for example, or the characteristic of the absence of equilibrium in the case of the balance scale.

Thus, one can distinguish three mains conceptions:

- The stable-equilibrium conception
- The instable-equilibrium conception
- The immobile-equilibrium conception

3.1.3 The sequence

The proposed sequence aims at unifying the three previous conceptions. The main idea of this sequence is to ask student to study situations representatives of those three conceptions in order to identify links, limits and definitions of those concepts.

The first set of situation comes from the most used system: the balance scale.

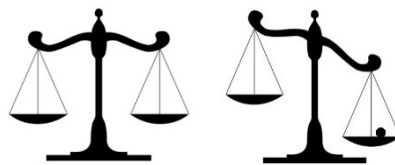


Figure 2. The balance scale situations

The second set comes from a common source of misconception: the human body.

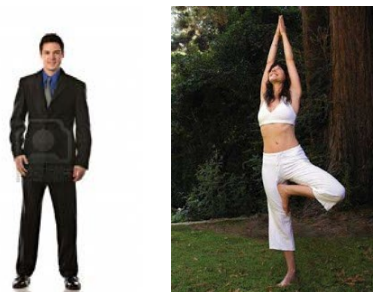


Figure 3. The human body situations

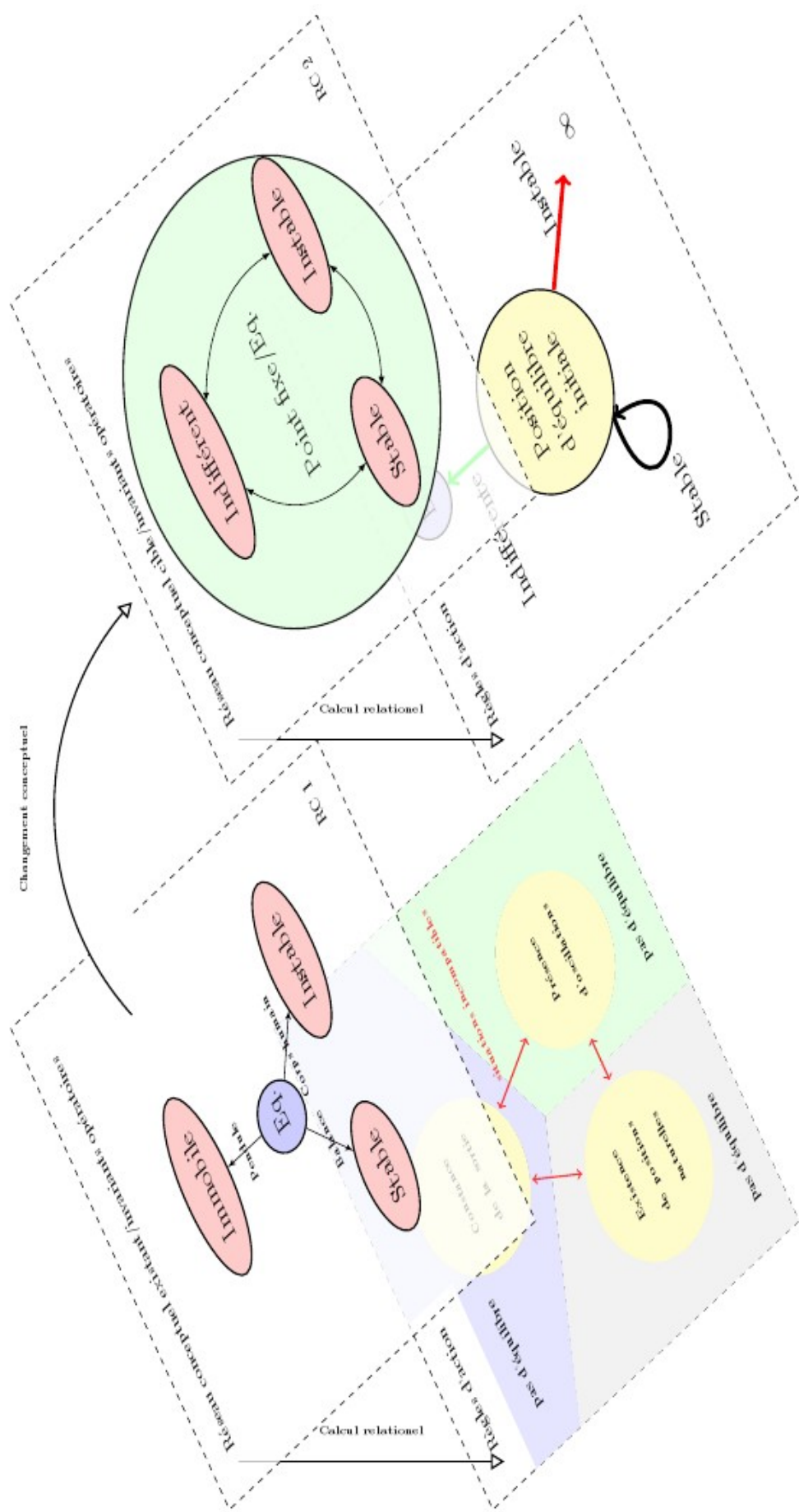


Figure 1. the proposed conceptual change scheme

The third set of situation is composed by “pendulum-on-a-cart” situations.

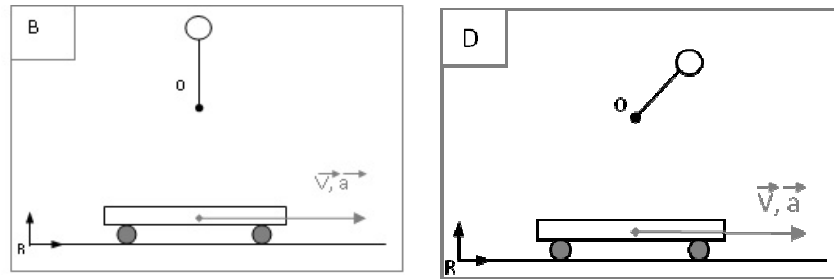


Figure 4. Pendulum-on-a-cart situations

Each of them represents a specific problematic situation with respect to the equilibrium/stability concept. The balance scale is the prototype of the (static) stable-equilibrium conception, the human body is an example of a “hidden” control system representative of the unstable-equilibrium conception, and the pendulum-on-a-cart allows the study of an equilibrium/movement combination.

The sequence consists of two sessions (one for the equilibrium and one for the stability) composed of an alternation of individual and group activities. Each of them implies the use of a paper-and-pencil short questionnaire with open and multiple choice questions. The table 1 resumes this organization.

Table 1. Sequence “equilibrium”

Stage	Status	System(s)	Questionnaire	Aim/question
1	Individual	Balance/Human body	MCQ + justification	Which system is in equilibrium?
2	Group	Balance/Human body	Open question	First definition of equilibrium
3	Individual	Pendulum-on-cart	MCQ + justification	Equilibrium of the cart? / the pendulum?
4	Group	Pendulum-on-cart + mvt.	Open question	Second definition of equilibrium

As describe in de Hosson (2011), the proceeding of the didactic engineering sequence is based on the verification of some hypothesis. The first one is that there is a repartition of the students in 4 sets: those who claim the equilibrium of the balance only in the horizontal case, those who claim the equilibrium of the balance in the two cases, those who claim the equilibrium only for the woman and those who claim the equilibrium in the man and woman case. In the next step, the teacher claims that all those cases are equilibrium cases and the next step aim at finding a first equilibrium definition, in group, which includes all those cases. This first definition could be a little bit away from the rigorous scientific definition, because it represents only static cases, thus it corresponds to the convergence process from the stable-equilibrium conception and instable-equilibrium conception to immobile-equilibrium conception (it is the second hypothesis).

The next and final stage aims at studying dynamic equilibrium cases. First, the teacher presents pendulum-on-a-cart figures and asks for the state of either the pendulum relative to the cart and of the cart relative to the ground. This kind of situation leads student to the studying of the frame of reference definition which is important to define the state of such a system. Next, the teacher is going to claim the possible (depends on the acceleration of the cart) equilibrium state of the two situations and students have to refine their first definition in order to reach an agreement for all situations (the third hypothesis). The verification of the three hypotheses allows the evaluation of the didactic engineering process.

The second sequence is based on the same architecture and situations but focused on the stability concept (not described here). It contains all the previous situations and a fourth one about a book on a table which is an example of an indifferent equilibrium (this kind of equilibrium which is the most present type of equilibrium in our everyday life but seems to be completely forgotten by students – according to a study based on 250 students in France and Colombia).

4 Results

This sequence was proposed to an engineer control course section of 38 students in a Colombian university at the beginning of the second semester of this year. Students were divided up in small group (four students) and for three of those groups the students were gathered according to their speciality (chemistry, electronics and mechanics). The 3 hours sequence (2 x 1h30) was audio recorded in order to analysing one part of the reasoning process of students during group activities (the socio cognitive conflicts for example).

The three hypotheses were verified but we noticed a repartition of misconceptions in the classroom a little bit different of our expectative. In fact, this is not very surprising because this kind of conception is very context-dependant and the socio cultural context plays a no negligible role. For example, the frequently use of a balance scale could affect the equilibrium perception and the understanding of the conditions for this state in a given class of systems (the use of this kind of device is for example quasi absent of French students' habits while it is more common in Colombia).

Moreover, we noticed the predicted mix-up between equilibrium and stability in the students answers at the first question. For example, 41% of students appeal to the word "stability" in order to justify the equilibrium of the system in the first individual question: for some students this argument is used in the sense "stability implies equilibrium", for others it is more in an exclusive relation sense "equilibrium OR stability". Nevertheless, the students reached the two objectives of this sequence in the time allowed for it, even if the effect of the mix-up seemed to be very difficult to change (even in the lasts stage of the sequence we could detect this confusion in some students answers).

Finally, from various conceptions of equilibrium and stability, they could identify the necessary and sufficient conditions for an equilibrium state, understood the stability as a characteristic of an equilibrium state, discovered the indifferent equilibrium and defined all those concepts from obviously unlinked situations. They could verify the match between the application of criterion they learned before (as a null net forces and net momentum) and the behaviour of a system (we called "*a posteriori*" approach).

5 Conclusion

This study shows that it is possible to improve students' schematics knowledge about equilibrium and stability using the Didactic Engineering process. To reach this objective, a model of the expected conceptual change has been developed. This model was used as a guide to drive the pedagogical process in the classroom activities. One of the mains objectives was to develop students' schematic knowledge making links between the previous students' declarative and procedural knowledge and the behaviour of the given systems ("*a posteriori*" approach). This approach promotes a conceptual change by putting students face to apparently well-known situation and asking them to test the operability of their conceptions. In fact, this aims at triggering a cognitive conflict which is the starting point of the conceptual change. It could be necessary to continue this process by other sequences in order to reinforce this process. Indeed, we assume that this process is a long way process that implies others activities to be effective. The next step could be for example a mathematical modelling situation which allows an understanding of the links between differential equations, the behaviour of various systems (including the previous systems) and associated disciplinary criteria.

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Educational Object for the Learning of Complex Numbers

Cassiano Scott Puhl*, Isolda Gianni de Lima**

Master Program in Science and Mathematics, Caxias do Sul University, Caxias do Sul, RS, Brasil

*Master's Student, **Advisor Professor

Email: c.s.puhl@hotmail.com, iglima@ucs.br

ABSTRACT

Complex numbers are a very important topic of knowledge for engineering course students. Without this knowledge, the learning of concepts related to electricity, for example, is restricted or of difficult comprehension. In interviews carried on with professors of several engineering courses, we concluded that learning in a mechanical way prevails when the subject of study needs the knowledge of complex numbers. In the mathematic educational context, we propose the creation of a set of apps which allow the student to interact with the knowledge in an active and exploratory way, aiming at meaningful learning. Our study, developed with those apps, becomes an important support resource to university levels subjects in which complex numbers are considered as knowledge acquired prior to the construction of new concepts, especially for Engineering students. With those apps, we expect to help professors, since their objective is to favor the comprehension of concepts and operations with complex numbers, as well as to give the students an opportunity to be active in their learning process.

Keywords: active and meaningful learning; apps; complex numbers; learning gaps.

1 Introduction

The educational environment is going through transformations that demand new ways of acting in teaching and learning. Many students aren't interested in learning and the professors need to update their teaching resources in order to reverse that scenario. A possible cause of that lack of interest can be related to the advent of the information and communication technologies. Easy access to information and knowledge puts the professors in a position where they are no more the owners of knowledge. They don't need to transmit knowledge, but to mediate learning, and this transformation isn't easy for the professors. Therefore, while educational environment doesn't adapt itself to this new tendency, education is, for some students, losing place and purpose. Teachers can't work with all the curriculum contents as in the past. Complex numbers content, for example, is being put aside by High School teachers, as shown in the researches carried by Batista(2004) and Mello and Santos (2005).

When teachers don't teach and students don't know basic Mathematics concepts in High School, there can be difficulties in higher education, mainly in Engineering courses, since these courses demand solid Math knowledge, from the basic to the professional formation subjects. In interviews carried on with Engineering professors of the University of Caxias do Sul (UCS), they reported that many students don't know complex numbers which are demanded for the resolution of Math problems in subjects such as Electricity.

Without knowing complex numbers, or even with a brief instrumentalization for the operation required, it's difficult for the student to solve problems that involve this kind of number. According to David Ausubel's(1980) meaningful learning theory, learning like that is meaningless for the students, because they don't have enough previous knowledge to anchor new knowledge, thus learning in a mechanical way. So, being 21st century educators, we can't teach mechanically, therefore we have to promote strategies for the students to learn meaningfully.

In this context, the aim of this study is to propose methodological alternatives that can help students to fill gaps in their knowledge of complex numbers, with the development of digital applications (apps) which, through manipulation and interaction, allow students to build their knowledge in an active and meaningful way.

2 Motivation

The stimulus for the development of the digital applications occurs when a teacher is concerned with education and learning of mathematical concepts. Math teachers don't expect students to learn the basics just for tests and assessments, or to be trained to use mathematical and algebraic processes mechanically. We, as teachers, want the students to learn about life. In the interviews carried on with professors, one of them declared that "when we say

we're going to work with complex numbers the students freak out". If the students get scared only by hearing the words, imagine what can happen when professors say they will need to operate with an imaginary unit. What does the student think of this approach? Probably he or she may think that this knowledge won't be necessary for his or her life and must be too complicated.

To understand this scenario, at school, or even in content review for later application in different contexts, what usually happens is that the teacher shows the students how to operate complex numbers and then they solve calculus with these numbers. In other words, what usually happens is that the content is passed to the students orally, with examples on how to make them, and a list of exercises to be solved according to the examples given. The algebraic skill produces no meaning or sense to these numbers. It's possible, and even common, to find students that solve several kinds of operations, through training or formulas, many times replacing mathematical ideas, without comprehension of the concepts involved. (LIMA, 2004; VILLAS-BOAS, 2011)

The professors who were interviewed don't have a specific subject to teach complex numbers in Engineering courses, and they expect students to bring this knowledge from high school. Realizing every semester that students don't know complex numbers, professors end up teaching the main ideas about the subject, in general about operations and some coordinate transformations, with fast explanations, that vary from fifteen to thirty minutes. Is it possible to learn how to add, multiply and divide complex numbers within this time? Add to that the transformation from the cartesian to the polar form of complex numbers to be applied in problems with electrical circuits. Learning meaningfully in such little time is difficult.

Technologies offer possibilities to promote meaningful and active learning through knowledge building, helping professors and learners to fulfill the necessity to teach and learn complex numbers. So, with some digital application, we intend to show that complex numbers are only complex in name and that the students have the basic knowledge required to understand this new numerical sets in a potentially meaningful way. Therefore, content would be meaningful and valuable, since the student would be able to understand complex numbers.

The initial motivation is based on the act of fostering moments or materials potentially meaningful for the students. Participation in congress, such as the XLI Brazilian congress of Education in Engineering(COBENGE) and VI International congress of mathematics teaching(CIEM), showed that the learning and teaching problem faced by the University of Caxias do Sul is not a particular problem, but a generalized one. Other higher education institutions are facing the same difficulties with basic math concepts and with serious consequences. According to Almeida and Veloso (2002) and Boero (2006), University drop-outs occur mainly in the first two years of graduation. The lack of previous knowledge is one of the main causes for quitting (FERLIN & TOZZI; SOARES, LIMA & SAUER, 2007). This aspect is another form of motivation, thus our study dimension is no longer local, being able to be expanded to other higher education institutions.

We expect with this study that students stop only memorizing formulas or problem solving algorithms. Actually what we expect is that students are able to understand, analyze and solve problems in different ways, using Math concepts skillfully and with recognition of their functions. The main reason for that is that Mathematics is also a science of application which favors the development and comprehension of concepts in other disciplines. If students are able to attribute meaning to contents, these will be useful and will be recognized as resources in other applications. On the other hand, students will be motivated to study specific Engineering concepts and learn the application, for example, of complex numbers in alternating current circuits.

3 Theoretical Referential

The digital applications presented in this study focus, especially, on concepts suggested by the professors interviewed and are based on Ausubel's theory to transform the student in the active user in the learning process so that knowledge is meaningful.

As said before, it's difficult for professors to break the paradigm of knowledge transmission. Thus, learning becomes a mechanical act and doesn't collaborate with the cognitive structures development. Then, when facing a problem situation, for example, many students can't identify the operation to be done, even if it is the same operation they could do before (in a mechanical meaningless way). To change this perspective, we suggest some possibilities to enhance the process of knowledge building, through active learning methodologies with the use of the technologies of information and communication.

According to Ausubel(1980), "the essence of meaningful learning is that new symbolically expressed ideas are related in a non-arbitrary and non-verbatim way to what the learner previously learned"(p.67). The content to be learned must be

related to the previous knowledge, called subsumers. The new concept is anchored to the cognitive structure, indicating that there's a non-arbitrary relation to learning. Thus, knowledge is not only words, rules or algorithms. It gets meaning, substance.(MOREIRA & MASINI, 2001-2011).

Besides this non-arbitrary and substantive relation, there are two other aspects to be highlighted so that a person is able to learn meaningfully. First, students must be willing to learn the contents, thus, they need to have a pre-disposition to understand and learn. Secondly, the course material must be potentially meaningful and very well constructed, so that the students can handle it easily as well as learn with it.(AUSUBEL, NOVAK & HANESIAN, 1980).

These are the main characteristics that must be taken into account so that the student can learn meaningfully, but as told by the professors interviewed, there is not enough time to construct previous knowledge in the classroom, there is time only to use them. Then, there comes the possibility of using technology tools to promote learning through active methodologies. The apps, we expect, will be potentially meaningful for the students, because they will serve as a bridge for them to learn alternating current circuits, being so, called advanced organizers.

According to Moreira and Masini (2001-2011), "Advanced organizers are useful to make learning easier working as 'cognitive bridges'". In other words, the previous organizer serves as a basic structure to achieve new knowledge. Only with this conception in mind it's possible to create a course material potentially meaningful(AUSUBEL, NOVAK & HANESIAN, 1980).

So, it's important to point out the use of technological resources as a support to methodologies that favor the learning development. The NTICs can help, because they allow the creation of learning environments and bring new ways of thinking and learning(BARIN, BASTOS & MARSHALL, 2013).

In this perspective, dynamic and interactive geometry can be used by professors in the process of knowledge building. There are several softwares, and also educational objects, that can help, mainly in the geometric visualization, making it possible to explore different situations and to construct hypotheses which can collaborate on making sense of ideas and concepts. When building a geometric figure, students have a starting point. They will be able, then, to test it, change it as many times as needed, in new experiments, aiming at rebuilding, confirming or ruling out a hypothesis (GRAVINA, 1996).

The proposal presented in this study involves the construction of apps that can lead the user to build some knowledge about complex numbers, especially the ones that the Engineering students, according to what the professors heard in the interview said, need to know: the geometric meaning of the imaginary unit of complex numbers; the sum or subtraction of complex numbers in their algebraic form; the transformation of complex numbers from their rectangular form to their trigonometric(or polar) form and vice-versa and the multiplication of complex numbers in their trigonometric form. We will follow a methodology of work similar to the one carried on by the professors Azambuja, Silveira and Gonçalves(2004). What makes the two proposals different is that in our project we use digital applications to concept building, but, likewise, with the purpose of promoting meaningful learning.

Therefore, we believe this proposal contemplates the aspects of Ausubel's meaningful learning, for:

1st The study about complex numbers will start with the manipulation and analysis of vectors to make the imaginary unit appears, as an operator that turns a vector in 90 degrees, not null. From the beginning of higher education, vectors are a topic of knowledge with what engineering students often interact. So, vectors are characterized as subsumers.

2ndWhen students understand the geometrical meaning of a complex number, highlighting the representation of the imaginary unit, theywill be able to understand easily more specific concepts, such as phasor diagrams in alternating current.

3rdStudents, who accept or look for a support resource to learn complex numbers, are willing to learn the content. Thus, they have a pre-disposition to learn.

4th Besides the application will be potentially meaningful, in case it gathers the three prior items. In other words, we expect that the resource, as support material in the form of a set of activities to be done, to be meaningful for the students.

However, for the material to be meaningful it's necessary to plan with care what is going to be used. Interactivity must be presented in the application, letting students explore, think over and analyze every situation, or they will be, again, information receivers only. Another aspect to be carefully considered relates to the graphic interface, which is an essential component to maintain students' attention and action. Even if students are willing to learn, if the application isn't pleasant and easy to handle, there's a risk of students end up quitting the application use.

Thus, to create an application, as a meaningful resource to support learning, it's strongly recommended to work with a team of at least three professionals: one to deal with programming, other to work with the graphic layout and the third one to work with the educational planning (FERNANDEZ & RIGO, 2012). These three skills can be found in one person as far as this person can perform them correctly, making it possible for students to develop active and meaningful learning.

As an active learning methodology, we expect students to interact with the knowledge object during the manipulation of the applications, guided by questions that conduct thinking and investigation, so that students are able to build meanings and concepts. One strategy to create an active learning methodology is the one called "just-in-time teaching" (JiTT), that has received enhancements and is enriching learning practice.

JiTT is a web based methodology, in which teaching aims at preparing students for a more complex learning context. Activities take place out of regular class schedule. So, students focus on one subject and come to class to talk to the professors, developing, then, their hypothesis and learning. Content studied in the virtual environment is strictly connected with the one developed in class. Thus, students come to class with meaningful knowledge for the learning process. The methodology presented in this study isn't distant education, but a resource to be used to expand students' knowledge (NOVAK, 2011; VILLAS-BOAS, 2011). This project is intended to involve students in activities that can be done outside the classroom, connecting these activities with others which are being developed in class, so the applications serve to fill gaps in learning. The applications are closely related to what the professor does in the classroom, they do the interaction between the high-tech and long-tech elements. The high-tech elements are the applications for the building of knowledge on complex numbers and the long-tech elements represent the classroom which is available for feedback and to expand the learning of alternating currents (SZPIGEL & MUSTARO, 2011).

In the classroom the teacher will be able to discuss the electric circuit analysis, with the support of complex numbers, indicating the previous study with the applications, not being necessary to divert the central focus of learning to teach some procedures with complex numbers. Thus, the activity developed in the virtual environment will allow students to participate during class, realizing the connections between the activities they accomplished at home and the content developed by the professor in the classroom.

Finally, we intend to put the teacher as a mediator, and to place students as the most important part of the process since they are the part interested in the learning process.

4 Methodology

To create the applications we used the application GeoGebra, that gather the algebra, geometry, tables, graphics, probability, statistics and operations resources. This software can be manipulated in multi-platform. We intend to make students think over, analyze and build hypothesis through the interaction with this applications.

Initially, we won't use the words "complex numbers" so students won't get nervous. Through questions, we intend to make students realize that real numbers aren't enough to solve some mathematical operations. It's important to say that we won't start the approach by solving quadratic equations. The knowledge about vectors is a necessary subsumer to create the need for complex numbers. Engineering students are often familiarized with vectors. They know how to solve operations such as the ones where they draw a vector with coordinates (2,1) and multiply in scalar by -1 (SPINELLI, 2013). "What is the resultant vector of this operation?" "How much does the angle between the initial vector and the resultant vector measure?" These are some of the questions the application will ask students, trying to establish interaction and make students think about their action in the application. Students will realize it's an 180° angle, and they will be able to confirm their hypothesis by using the measuring angle tool in GeoGebra, as can be seen in Figure 1 below.

In the next application, students will build vectors to get to know the software. Doing this they will be interacting and recognizing the software potential. At this point, the application brings a challenge: "How much should we multiply a vector by in order to make it rotate 90° ?" Initially the application proposes a hypothesis: when multiplying the vector by -1 the result is a turn of 180° , then by multiplying for half of that, it will turn 90° , as can be seen in Figure 2. Students will make the operation and will conclude this number can't obtain a 90° angle. After that, there's another question: "Which hypothesis have you built? Test the hypothesis you have and check by how much you should multiply the vector so that it turns 90° ". The active students will come up with some hypothesis, and through them, we believe they will realize that by multiplying a vector by a scalar, there's no real number that can produce a 90° turn.

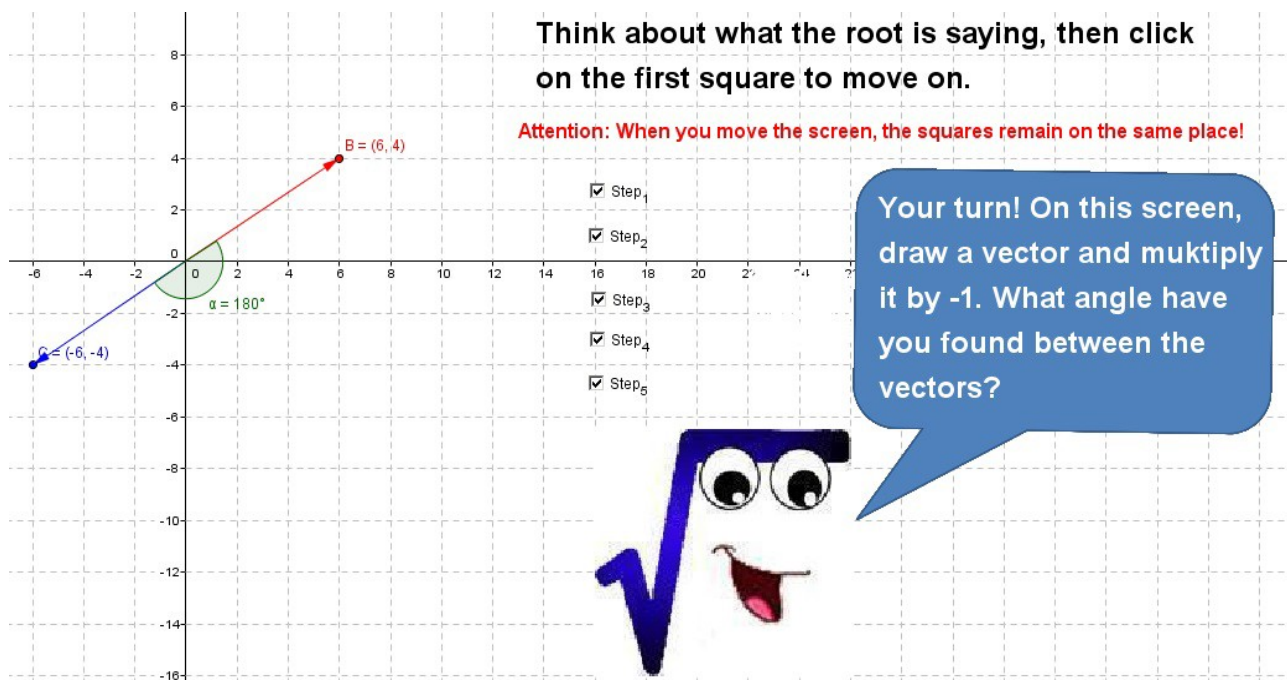


Figure 1: Application talking about 180° rotation

If there is no real number to make this operation, students should expand the numerical content to include this function. After that, another application shows the relation between the abscissa axis, for the real part, and the ordinate axis for the imaginary part of the complex number, and only then, in the same application, a formal definition is shown.

It's important to observe that the imaginary unit of the complex number is represented by the letter "i" in Math, but in Physics and in other disciplines which use vectors in engineering, it's more common to use "i" to represent electric current and, so, "j" is the letter to represent the imaginary unit.

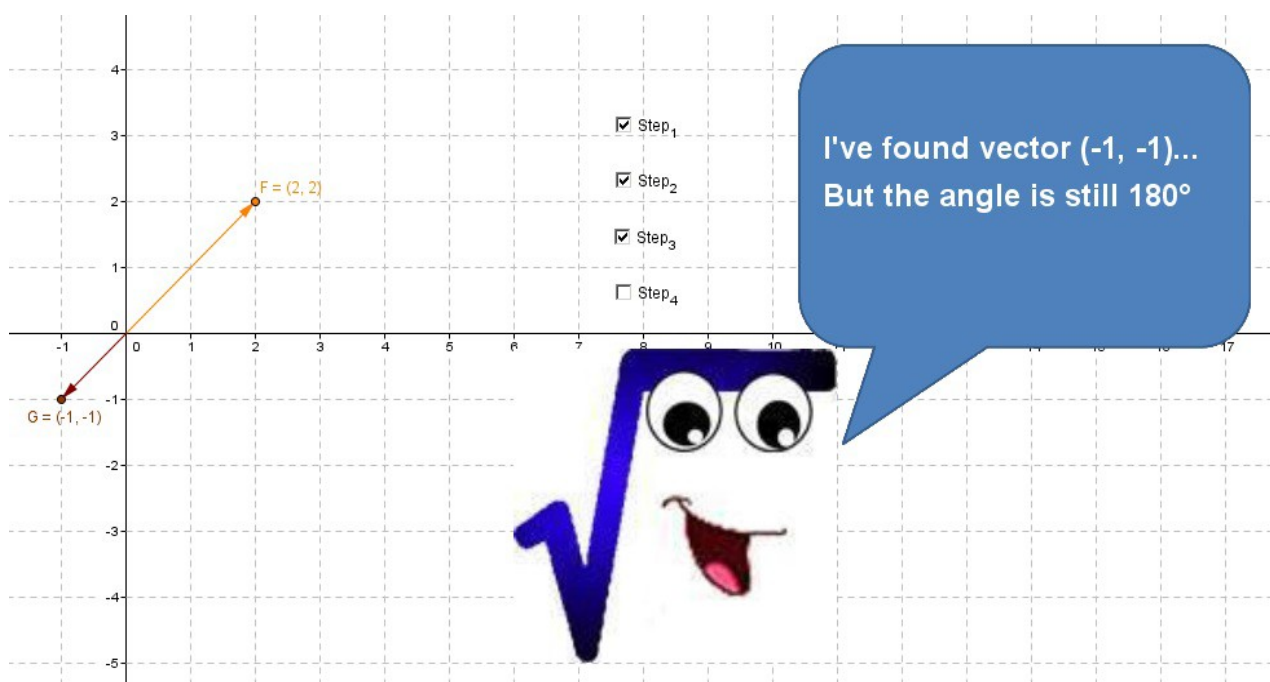


Figure 2: Testing a hypothesis to make a 90° rotation in the vector

After the interactions and hypothesis, it's students' turn to create and manipulate the application, marking vectors as representative of complex numbers. At this point, students are a bit more familiarized with complex numbers, the definition of the Argand-Gauss plan is presented, which is very suitable to represent complex numbers.

For the sums and subtraction of complex numbers, another application suggests to students to sum complex numbers as they sum vectors, making them realize they are adding real and imaginary parts.

Another aspect suggest by the interviewed professors is the meaning of the vector multiplication, as a complex number, by the imaginary unit "j". Interaction begins by representing the vector coordinate(1,0) and with the following questions: "Is another vector obtained by multiplying this vector by "j"? "Which angle is there between the initial and resultant vector in this multiplication?". Students will see or measure a 90° angle. This meaning is important, because when studying phasors diagram in alternating current, and also the tension diagram, the resistor tension forms with the capacitor tension a 90° angle and so, the tension is advanced in 90°. The same happens between resistor and inductor tension, being, this time, the resistor tension delayed in 90°.

By what the professors said, the sum of complex numbers is applied without difficulties, but when multiplication is needed, the process becomes complicated. They reported that they don't approach multiplication in the cartesian form, but only in the trigonometric form. For engineering professors, this is known as the polar form of a complex number. When representing the polar form of a complex number it's necessary to calculate $|z|$, that is the module, and θ that is the argument of z , being represented by $z = |z| \angle \theta$ or $|z| \theta$.

Before using the trigonometric form of the complex number, the application will help in the building of the trigonometric form: $z = |z| (\cos\theta + j \sin \theta)$. Thus, with some basic trigonometric knowledge, there will be a mediated talk to find the complex number module, as well as some relation to the module with the real and the imaginary component.

The application, then asks the question: "How can you represent a complex number through trigonometric relation?" First, the application will suggest to students to calculate the complex number module for all the triangle elements. Then it will ask: Which trigonometric relation can be used to represent the real part of the complex number? We believe students have this trigonometric knowledge, so they will define that: $\cos\theta = \frac{|z|}{a}$, finding, then: $a = |z|\cos\theta$.

Using the same idea to find the value for the imaginary part, being: $b = |z|\sin\theta$. After that, replacing the Cartesian form of the complex number, students will get to the trigonometric form. In case students don't remember the basic trigonometric functions, the application will ask: Do you remember sine, cosine and tangent in a triangle rectangle?" If students don't remember, they will be challenged to look for definitions of these trigonometric functions. The answer won't be given, but students will be taken to look for them, trying to develop, then, an active learning attitude. That will happen since students interact and are willing to learn.

After calculating the trigonometric form, it's necessary to calculate the argument of the complex number. The application will ask: "How can you calculate the angle between the vector and the axis of the real positive numbers?" With the trigonometric functions known before, it will be suggested to students to use the arctangent to calculate the θ angle. Now students can define the complex number in the trigonometric form, the application will show the polar form used in engineering courses.

After the reflexive construction, there's some practice with complex numbers, when students will be asked to transform the numbers from the Cartesian to the polar form, transforming as well, numbers that have only a real or imaginary part.

Another operation to be approached is the multiplication of complex numbers, in which the result is obtained by multiplying the modules and adding the arguments.

With the imaginary unit multiplication idea built, where the angle always increases 90° counterclockwise, the application will suggest the multiplication of other complex numbers. During the complex number multiplication, students should get to a moment where they will be multiplying sines and cosines. It will be proposed, then students to look for trigonometric relations, involving the multiplication of sines and cosines, as for example: $\cos(a+b) = \cos(a)\cos(b) - \sin(a)\sin(b)$ and $\sin(a+b) = \cos(a)\sin(b) + \cos(b)\sin(a)$, so they can answer; "What's the relation between the complex number modules that are being multiplied and the number module that results?" We believe students will realize that the module will be the multiplication of the modules, and that the argument will be the sum of the arguments. Besides realizing these relations, students will make a demonstration of why this action is done when solving complex number multiplications. After that, it will be proposed to students to test their hypothesis, multiplying complex numbers and confirming that they should multiply the modules and sum the arguments.

For the division, it will be used the idea of doing the operations inverse to the ones done in multiplication, in other words, if in the multiplication the modules are multiplied in the division they will be divided. For the argument the same analysis will be done, when multiplying, the arguments are added, then, when dividing, the arguments will be subtracted. Again in division the trigonometric form is used, because, for division in the Cartesian form the rationalization method is used, and by other experiences, the last would be more difficult to be understood and applied by the students.

This is the sequence of applications with which we aim to modify the role of the professor actions, which consists of fifteen to thirty minutes explanations, and according to what many of them have told us, is meaningless for the students.

We believe that when using this didactic sequence students will build meaning with an active learning methodology. The applications are in the construction phase to be applied in the first semester of 2014, in, at least, two groups of engineering students that use complex numbers for the alternating current circuit analysis.

After this first test, the application will be improved with the students and professors contributions.

5 Final Considerations

The apps described in this paper are being created, researched and planned to help students to get motivated to use them and develop individual learning techniques realizing that specific activities take them to meaningful concepts. For the professors, this paper tries to add ideas in order to make classes more interesting by adding topics for discussion with students' participation and bringing concepts that take into consideration mathematical knowledge that pose no difficulties to the learning process. Therefore, we also hope to help and motivate students to keep studying Engineering, which is a major that shows a high number of drop-outs. These drop-outs are caused most times by students' difficulties with previous mathematical knowledge which are needed as the rocks for building further knowledge in different basic subjects.

The apps created here are being integrated in a virtual environment which is set up as a learning object which can be used as support to rebuilding knowledge for complex numbers at university level in teaching Mathematics. This process happens in the Engineering courses as proposed by this paper. Furthermore, the major objective is to keep the learning object as a support resource material or as course material to build structural concepts of complex numbers in school and high school levels.

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Meaningful Learning and Trigonometry Activities

Cassiano Scott Puhl*, Vanessa Cristina Rech Viganó**, Isolda Gianni de Lima***

Master Program in Science and Mathematics, University of Caxias do Sul, Caxias do Sul, RS, Brazil

*Master's student, **Master's student, ***Advisor Professor

Email: c.s.puhl@hotmail.com, vanrech@hotmail.com, iglima@ucs.br

Abstract:

Trigonometry is a knowledge topic which relates to many other common concepts from Mathematics and Engineering. It is also a pre-requisite to develop many learning processes with meaning and understanding. However, it is usual that students do not comprehend or notice when basic Trigonometry concepts are needed. It is also common that students have learning gaps and thus, even being aware that they need Trigonometry concepts, they don't know how to apply them (possibly due to meaningless mechanic basic learning processes). In attempt to promote active methodology revision, we intended to develop meaningful learning of the main trigonometrical concepts with a workshop project to promote students' engagement while manipulating, building and measuring materials, as well as using an innovative teaching methodology which has been successful internationally, named Peer Instruction (MAZUR, 1997). Thus, this workshop project seems to be an important idea as support resource to disciplines that demand Trigonometry as previous knowledge and to build new concepts. This article presents a set of activities that aims at promoting meaningful study of concepts of Trigonometry, which is supposed to significantly collaborate to the improvement of learning conditions of Engineering students.

Keywords: trigonometry, workshop, active and meaningful learning, Peer Instruction

1 Introduction

In the school environment, it is still common to find traditional teaching methodologies, in which the teacher exposes formulae and the student only receives and memorizes fixed ideas. This generates short-term superficial mechanical learning, both for High School and College students (LIMA, 2004). In this case, the topics are simply memorized, and are only of value for those who want to pass tests or exams, such as the vestibular. This is how Trigonometry is usually taught, out of context and without meaning for daily-life situations. Being far from the students' reality, the topic becomes boring and meaningless, mainly if it is presented as a simple set of calculations and formulae. When studying Engineering subjects, if the student does not have the knowledge of the basic Trigonometry properties, it is understandable that he or she becomes unable to grasp new topics and, thus, uninterested with the studies and, at times, the course itself.

When formulating a workshop to build and strengthen Trigonometry concepts, it is possible to transform this area into an important foundation for the topics to come, especially focusing on Mathematics for Engineering, subject in which students frequently show learning gaps and struggle to grasp new concepts.

Usually, in Brazil, Trigonometry studies start in the 9th year of Primary School and get deeper and more complex in High School. However, it is noticeable in any education level that students don't see the point in studying Trigonometry. To change this scenario, we created a didactic sequence to help College students to learn meaningfully, based on ideas by Kessler & Paula (2010) and the professors Lima, Sauer & Sartor (2011).

Searching for an active methodology for trigonometrical concepts, we propose a workshop that makes possible for the students to engage more, inspired by a successful teaching innovation that has been internationally spread, called Peer Instruction (MAZUR, 1997).

Peer Instruction was first coined for University Level in the 1990s by Professor Eric Mazur, from Harvard University (USA). In the last few years, the method has quickly spread through the world, to the point of being used by many teachers and professors nowadays in many countries, especially in North-American, Canadian and Australian universities (CROUCH et al., 2007).

According to this method, the teacher is supposed to present the target topic for 20 minutes at most and then give students a cloze test to be done individually in 2 minutes (MAZUR, 1997). The answers can be informed to professors in different ways, such as clickers, flashcards, computers or internet-based systems.

If the accuracy rate is between 35% and 70%, students form small groups, preferably with classmates who had chosen different alternatives, to discuss their answers for about 3 minutes and then vote again. This gives students the opportunity to think individually once and then collaboratively, before they are given the correct answers (MULLER, 2013). By discussing with classmates, students are able to argument when trying to convince others and, when questioned, they have the chance to understand, comprehend and learn the target topic. After this initial discussion moment, the groups answer the questions once again and, in case there are still great divergences in the answers, a whole-group discussion is conducted. The teacher/professor mediates the process and conducts the discussion in the accurate direction, so that the students who made mistakes understand why.

This way, the students are believed to become active subjects in their learning process and the teacher a mediator, with fundamental focus the active, meaningful and constructive learning of Trigonometry's basic concepts, theoretically based on Ausubel and Vygotsky.

This is the first stage in the workshop, which gives us a head start in the objective of promoting an early study of basic concepts, rebuilding them to, later, involving students in practical activities to solve problems. Active learning, according to Polya (1977), means that "to effectively learn, the students must find out by themselves as much of the topic as possible, given the circumstances". In this perspective, the teacher must offer subsidies for the student to build knowledge, through different methodological strategies and potentially meaningful activities, such as the ones suggested by the Peer Instruction methodology.

2 Motivation

Our motivation when planning the workshop was to promote better learning conditions and to suggest a transformation in the current teaching practices and habits, trying to improve the quality of the Mathematics teaching practice through a dynamic methodology, in which the student is active in building concepts.

Students, together with society, are inserted in a technological context in which information is easily found. However, the teacher, who only transmits knowledge, hasn't been able to achieve success because the meanings of the target topics seem to be missing.

Learning is an individual phenomenon, personal for every one when building knowledge. Some people are more autonomous, whereas others are more dependent of someone who teaches and motivates them externally, in a higher or lower scale. This is a characteristic of active learning, which requires the students to be cognitively active. To promote this condition it is crucial to foster curiosity and interest, which can be achieved with the use of more involving, dynamic, fun and challenging teaching strategies.

When learning Mathematics, students struggle if they aren't given learning conditions that allow them to comprehend the concepts and the language.

Some Engineering students don't have the basic Mathematic knowledge and comprehension in their cognitive structures, which generates difficulties when building new concepts for application in the area. It is noticeable, for example, that many of them need a calculator to establish the sine of 30 degrees and can't represent this idea geometrically nor can they identify the difference between function graphs such as $y = \sin x$ or $y = \sin 2x$. Gaps as basic as these generate frustrations and dislikes related, many times, to the Engineering course itself (LIMA, SAUER & SARTOR, 2011).

This workshop hasn't been used with Engineering groups yet and, possibly, some aspects will be improved with the participants' suggestions, since the focus is to create a favorable environment for building Trigonometry concepts by Engineering students.

3 Theoretical background

Learning is a process through which a subject acquires new pieces of knowledge, assimilating and placing them inside their cognitive structure, making them meaningful and able to change the way of living, acting and thinking about the world around them. When people learn, they add new information to previous knowledge, connecting and relating both things (AUSUBEL, 1980). Moysés (2000), who studies the learning theories stated by Vygotsky, says that cognitive development only happens via social interaction. In other words, people learn by interacting with other people and the environment. This way, Ausubel and Vygotsky's theories indicate how the activities can relate in our workshops; the students already have some Trigonometry knowledge, in an indefinite complexity level. This

knowledge will be broadened during activities with rulers and pairs of compasses and also during problem-solving strategy activities, under the orientation of the teachers and constant interaction with classmates.

According to the National High School Guidelines (Parâmetros Curriculares Nacionais para o Ensino Médio – PCNs):

[...] traditionally Trigonometry is presented out of context, detached of its implications and uses, and too much time is dedicated to algebraic calculations of identities and equations at the expense of important aspects of the trigonometrical functions and their graph analyses. What must be assured are Trigonometry's applications when solving problems that involve measures, especially to calculate inaccessible distances (PCN+, 2002, p118).

Following the suggestions from the National High School Guidelines, our workshops are developed as to propose a meaningful study of Trigonometry that is able to give students the chance to rebuild concepts and apply them in problem situations, being them real or not. To propose and act with pedagogical workshops is something that contributes to renovating the learning environment and allows students and teachers to reflect upon knowledge dealt with, and also to build knowledge creatively and collectively. This way, the teaching-learning process becomes more effective as it develops interest for practice, investigation, observation and promotes knowledge building with object manipulation, sharing of ideas and dialogs.

In such situations, students use previous knowledge and are, according to Moisés (2000) (when he explains Vygotsky's theory) in the actual development zone. In this case, we relate to the right triangle's characteristics. In order to acknowledge and develop this previous knowledge, we propose a set of questions to be answered with the use of the internet, aiming at recognizing the necessary previous information to produce new knowledge, from the potential development zone.

Ausubel's meaningful learning is comprehensive learning and

is characterized by the interaction between new and previous knowledge. [...] new knowledge acquires meaning to the learner and previous knowledge gets richer, unique, elaborate in terms of signification and gets more stability (MOREIRA, 2005).

In order to promote learning, the teacher must be a facilitator, mediator in the process. The teacher must stimulate curiosity, promote interaction among the participants and share concepts. The student, in turn, must be pre-disposed to want to learn.

According to Ausubel (1980), students' previous knowledge anchor new knowledge and get broadened by them. This is how meaningful learning occurs. Besides Ausubel's theory, we also used Vygotsky's development zones.

Vygotsky states that learning depends on the interaction between students, teachers, society and the environment where they live. He also divides knowledge development in two levels: the actual development level is the one the student already has, related to the problem-solving capacity; the potential development level is the one the student is expected to reach. To solve problems in this level, for example, students need help from teachers or peers (FINO, 2001).

To evolve from one cognitive development level to the other (with real learning), the subject must make the target knowledge a part of his or her cognitive structure, not only manipulating it but understanding it. Vygotsky also states that the main tool to get to this level is language.

Language, oral or written, is the first and foremost comprehensive device and students use it to understand and to explain whatever content they deal with. Vygotsky's theory may be a way to elaborate strategies and practices for students to demonstrate what they have or haven't understood and to help struggling classmates (PRÄSS, 2008). The teacher's role is to mediate and to be close to the students in this knowledge building process. The teacher serves as a guide who shows the way for students to establish conclusions and test them in the learning environment.

Thus, Ausubel and Vygotsky's ideas complement each other and base theoretically our workshops. This way, we believe to be contributing significantly to establishing support to students who need to rebuild basic concepts before moving on at University, where they will be able to use them as anchors in Engineering disciplines. New concepts, if funded by basic ones, will be more easily dealt with, which tends to decrease the failure and drop-out rates.

4 Methodology

This article presents a set of teaching activities that aim at providing meaningful learning, based on Kessler and Paula (2010) and also Lima, Sauer and Sartor (2011), to help students overcome learning gaps and improve Trigonometry knowledge. They are suggestions that can be developed in regular class schedules or in workshops about concept building and application of Trigonometry.

The workshop's methodological set is organized to make students able to build concepts about trigonometrical ratio in the right triangle and in the trigonometrical circle. These ratios are to be built through activities related to their definition as ratio between the right triangle side measures and the tangent to determine inaccessible point distances.

Seven activities are intended to be developed in the workshop. Along the process, students are given the opportunity to work collaboratively and to use tools such as rulers, compasses, protractors and squares. This type of learning activity has been forgotten nowadays, and many Engineering students struggle when it is necessary for them to use these tools, which is basic knowledge in order to comprehend and represent angles, straight lines, perspective and, above all, to represent three-dimensional figures.

All the knowledge built and thought about will be subjected to debates in small groups and then explored by the whole group, so that there's a reflection moment and meaningful learning is more likely to happen. The initial questions will be dealt with in multiple choice style, as proposed by Mazur (1997).

The first activity is a cloze test which serves to evaluate students' previous knowledge as Ausubel's learning theories suggest, as this previous knowledge may be used as foundation for the new knowledge substantively and non-arbitrarily. "The most important factor for learning is what the students already know. This is something that must be investigated and teaching must start from these data" (Ausubel, Novak & Hanesian, 1980). Right after the first questions, depending on the answers, the teacher is able to decide on strategies to help students build basic knowledge related to the right triangle's properties. It is intended that, then, participants are able to calculate approximate values such as the sine of 38° , tangent of 65° and secant of 80° by drawing right triangles with accurate approximations, which are, frequently, more meaningful than exact values discovered with the use of calculators. By doing this, students may realize that the values of trigonometrical ratios in acute angles can be stated when drawing right triangles. Thus, the sine of 30° stops being just a meaningless approximate value of 0.6, but the ratio between the measure of the cathet opposite to the 38° angle and the hypotenuse's measure in a right triangle which sides measure 3.2, 4.1 and 5.1 (3.2 being the cathet opposite to the 38° angle and 5.1 being the hypotenuse, as represented in Figure 1.) If students reach the correct answer at first, it is not necessary to move on to small groups and whole group discussions. However, if there are divergences, students are supposed to discuss their results and the strategies they used to find them. The teacher, working as a mediator, has students argument and repeat the practice, until the moment when all students have built the concept.

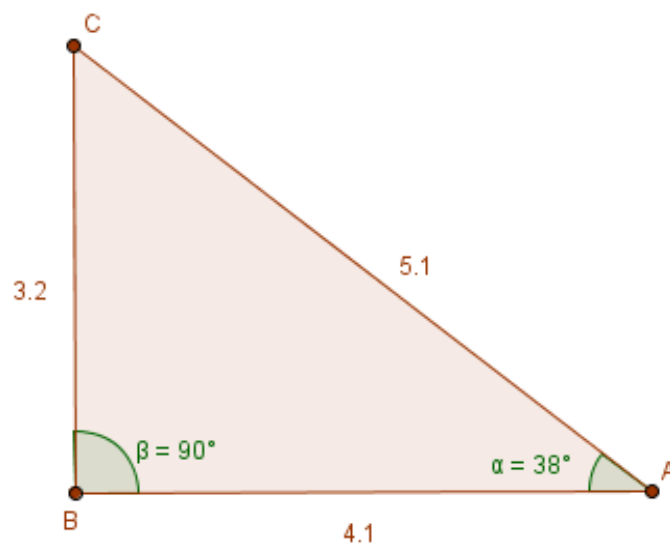


Figure 1: Right triangle with a 38° angle

By understanding this process, the student can trace the inverted way of building a triangle using a trigonometrical ratio. This is a valid way to evaluate if students understand the ratios' meanings. Using the same instruments from the previous activities, the teacher can now move on to a new one, in which students should be able to calculate the approximate values of an angle whose cosine is $3/5$, an angle whose cotangent is $3/5$ and an angle whose cosecant is $3/5$. To draw the right triangles, students will be given rulers and protractors in order to define the triangles' angles. Another interesting aspect of this activity is the fact that students must know the ratios that determine cosine, cotangent and cosecant, for without this knowledge, they won't be able to measure and draw the triangles. Now, if the calculator can give us the exact ratio values, why calculate them manually? Indeed, the calculator is a great tool for Engineers, but we propose a reflexive, meaningful, active study with which students are able to understand the rationale behind the numbers, to build concepts and use them in situations. Figure 2 represents an angle whose cosine is $3/5$. This way, the students are able to comprehend a calculation done mechanically by the calculator. Once again, the teacher evaluates if there is consensus or divergences in the answers and, if need be, further develops the topic. It is expected that there are fewer mistakes now than in the previous moment, since both activities deal with similar concepts.

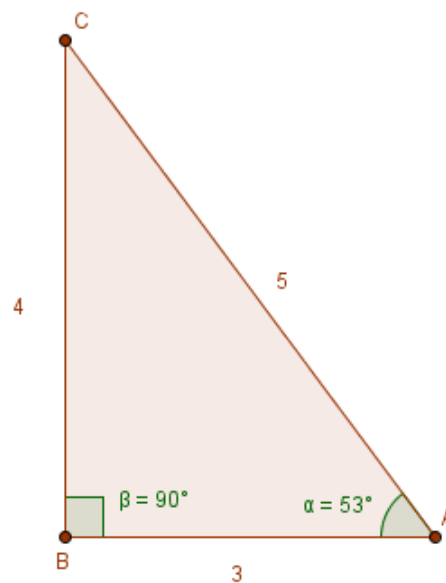


Figure 2: Angle whose cosine is $3/5$

The next activity is the study of a trigonometrical circle, since with it is also possible to represent any trigonometrical ratio's value, and also make geometrical drawings using the ratios' values. This is a more complex study than the right triangle's properties. Probably, in the initial cloze, few students will demonstrate developed knowledge about the trigonometrical circle. Thus, it may be necessary for the teacher to deliver an initial explanation, for 15-20 minutes, before entering the Peer Instruction practice. This activity deals with the same values used in activity 2, but in a trigonometrical circle, which may give the future Engineers the chance to reflect upon some aspects such as the fact that the trigonometrical circle has radius equal to 1.

Questions such as "If the angle has secant 4 and belongs to quadrant 4, which are the values of the other trigonometrical elements?" probably will generate various answers, as information such as the quadrant arches' positions may not be consensual. Because of this, the discussion tends to be constant and the argumentations might become confuse; this can be a hard but rich process, favorable to knowledge building, if adequately mediated by the teacher.

Thus, by knowing one of the trigonometrical ratios of a given angle, it is possible to know all the others. This way, the famous trigonometrical values of the notable angles (30° , 45° and 60°) in any quadrant can be found out by the use of the trigonometrical circle.

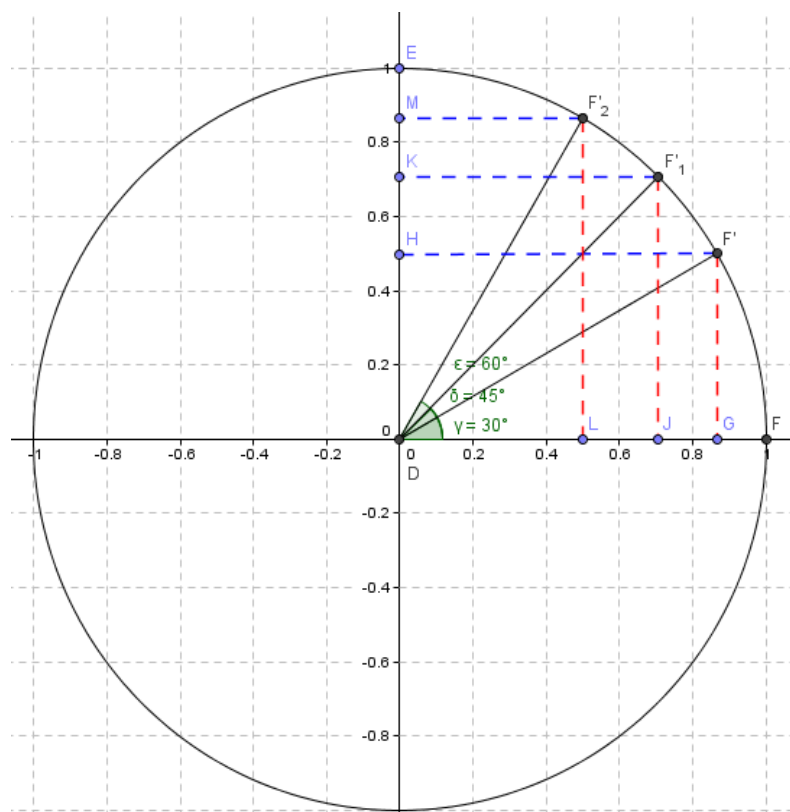


Figure 3: Notable angles' sine and cosine

Figure 3 represents the approximate values of sines and cosines of notable angles, represented by the straight line segments DG, DJ and DL as values of the cosines of 30° , 45° e 60° , respectively, and the approximate values of the sines as the approximate measures of the segments DH, DK and DM, respectively.

An interesting aspect of this activity is the tangent study, as in engineering subjects this is a commonly applicable concept. By drawing a trigonometrical circle, the segments which determine the values of trigonometrical tangents, and checking them by dividing the same angle's sine and cosine, students will be familiarized with this piece of knowledge, which can help them cope with the Calculations disciplines' contents. The fifth proposed activity is to find the other trigonometrical relations of these angles, using the expanded trigonometrical circle, by representing the angles and ratios obtained.

The next workshop practice does not begin with multiple choice questions, as the students will be invited to measure heights on the streets. Depending on the practice's location, the measures will be related to houses, trees, buildings or street posts. For this reason, it is impossible to pre-establish measures, but students will be active in their learning processes. By doing it, students will deal with real situations to measure distances and angles, also using a tool illustrated in figure 4, a homemade theodolite. To make the theodolite, it is necessary to have a protractor photocopy, two wooden sticks, sticky tape and stretchy rubber. We also suggest the use of two smartphone apps, Smart Protractor and Angle Meter, to measure angles with more realistic values.

In the end, each group will have dealt with a set of problem situations, whose solution involves trigonometrical ratios of the right triangle and the trigonometrical circle. Each group then presents their situation and resolution to the whole group.



Figure 4: Homemade theodolite to measure objects

To evaluate the workshop, the teacher should create yet another initial cloze test, to check if there was an evolution in understanding of trigonometrical concepts by the students. This way, it is possible to prove the efficacy of the methodology, besides making students active in their learning processes with meaningful learning and interest for mathematical properties. Mathematics is thus presented in a contextualized way and students use Trigonometry throughout the workshop to realize how important it is to daily-life applications as Engineers-to-be.

5 Final considerations

Learning is, indeed, a task for learners. Teachers have the important role of providing students with the right conditions and tools to make learning a reality. With the use of the workshop hereby presented, we hope to collaborate to improve teaching and learning conditions for Engineering students and professors, by suggesting effective, active and meaningful learning strategies and environments.

This workshop presents new conception possibilities, as students become active subjects in their learning processes and are able to express themselves, review and deepen their Trigonometry knowledge. By interacting with the professors and classmates, students are able to identify difficulties and comprehend theoretical and practical topics.

The workshop tries to create a reflexive environment of concept creation, which allows participants to notice the importance of meaningful learning. The tasks here suggested tend to produce more dynamic, pleasant and meaningful actions to learn and share knowledge. By doing so, the teacher helps students to learn to think, to research and to reorganize previous knowledge, as a means to reach potential development.

We believe to be contributing to better learning conditions by implementing Mathematics knowledge as contextualized scientific data, useful for many professional areas, notably Engineering, and by demonstrating how Trigonometry tends to be a basic knowledge area for more complex advanced studies.

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Interdisciplinary project based constructivist learning theory and case-based studies

Cecília Sosa Arias Peixoto, Alcinei Moura Nunes and Fernando Silvestre da Silva

Centro Universitário Salesiano de São Paulo – campus São José – Campinas, SP, Brazil

Email: cecilia.peixoto@sj.unisal.br, alcinei@sj.unisal.br, fsilva@sj.unisal.br

Abstract

This paper presents an interdisciplinary project based on the development of a project that link together all of the semester disciplines of the student into two theoretical frameworks: constructivist learning theory and case-based studies. At the end of the semester, a questionnaire was answered by the students about the project, in order to assess the performance and to ratify the teaching method. The results were preliminary, but has shown a tendency on creating a new knowledge from practical work, improving the inter-personal relationship with group performance and the critical sense, reinforcing the theory and presenting new points to be worked on in upcoming projects.

Keywords: constructivist learning theory; situated learning theory; problem-based learning.

1. Introduction

One of the teaching and learning strategies featured in several institutions is the problem-based learning, PBL – *Problem-Based Learning* (Arantes, 1998). In PBL, the knowledge construction occurs in a collaboratively way, with the student having wide participation during the resolution of the learning situations (problems) formulated by the teachers of the course, regarding the educational objectives to be achieved. PBL prioritizes self-directed learning, with the motto: “teach the student to learn”, by presenting problems to be solved. Through the solution of the problem-situations, the student acquires knowledge in a search-teach-knowledge process that values the experiences and goes toward the constructivist learning theory (Ausubel, Novak, & Hanesian, 1980). Motivated by the results obtained in several universities in this sense, the UNISAL courses of Bachelor of Engineering and Technology has adopted this learning method. As a way to evaluate the results, a database was created for the course of Technology in Automotive Systems of UNISAL. To this class was proposed to design and implement a Digital Tachometer project. This project interrelates all of the semester disciplines of the student: Materials and Automotive Components, Mechanical Design, Metrology, Microcontrollers and Feedback Systems. This paper presents an introduction to the teaching aspects chosen for the development of the project (section 1). Section 2 presents the Construction of the Digital Tachometer, study of a case developed with the PBL approach. Section 3 presents the results obtained through the application of questionnaires to the students participating in the project. Section 4 presents the conclusions.

One of the main criticisms in the teaching-learning process is, according to Dede (2008), that the students many times are incapable of applying what they learned in contexts in situations in the real world. It is prominent in the learning-teaching process that, in the knowledge of Papert (1996), the student must develop his own knowledge instead of simply assimilating the contents and skills of a teacher. The constructivist theory emphasizes that the students build new knowledge and understanding based on what they already know from which new knowledge is formed (Vygotsky, 1978). According to Dede (2008) students learn through the construction of knowledge based in preexisting relations of content and skills. In turn, the teachers organize and establish the logical relation between the knowledge in order to facilitate the cognitive process. In this system, the student updates somehow his knowledge schema, compares it to what's new, identifies similarities and differences and integrates them in his cognitive schemas (Zabala, 1998). The process will only succeed if the student can “receive” knowledge, keep it and know how to retrieve the information stored in his memory. To Ausubel Novak and Hanesian (1980), it is of vital importance that the new information can be related with the basic ideas already existing in the cognitive structure of the students.

Another theoretical framework interdependent to the constructivist learning and important in this project is the situated learning theory (Brown, Collins & Duguid, 1989). Situated learning theory postulates that all knowledge

assimilation occurs within a specific context and the quality of the learning process is the result of the interactions among people, places, objects, processes and culture within the context where the process was inserted (Brown, Collins & Duguid, 1989). In this sense it is wished to provide consolidated learning experiences that contemplate the context, the interpellations among team members, the objects and processes in the pursuit of problem solving. The theoretical issues presented are the foundation that the interdisciplinary project can assist in the consolidation of the knowledge presented in the semester courses.

The development of this interdisciplinary project is aligned with the constructivist learning theory, once it places the student within the context of solving real world problems. The mentor-teacher facilitates the processes of participatory learning, with reciprocal teaching and with multiple ways of representation. The situated learning theory was also considered, establishing the project and creating situations that favor a participative process among the teams in a real context of development and handling of objects in the elaboration of the digital Tachometer.

2. Project Description

The project is based on the development of a prototype using PIC (Peripheral Interface Controller) microcontroller and rotation sensor embedded in a commercial motor vehicle that performs the digital measurement of engine speed.

The PIC16F877A microcontroller (Mashhadany, 2012) 40-pin DIP (Dual In-line Package) format used has as main features: operating frequency of up to 20 MHz, memory for data storage non-volatile (EEPROM: 256 bytes) 8 bit, data memory (RAM: 368 bytes) 8-bit, program memory (Flash: 8 Kbytes) 14-bit, 15 interrupts types, three timers (Timer0, Timer1 and Timer2), eight analog input pins 10 bits, serial communication and modules PWM (Pulse Width Modulation) (Rongen, 2009).

To measure rotation was used hall effect sensor (Bicking, Wu, Murdock & Hoy, 1991) Linear 3517 that is characterized by the voltage between 0 and 5V, and temperatures between - 65 and + 170 degrees Celsius. This sensor basically works as follows: connecting a voltage on its pins external, pulses can be collected by the center pin caused by the approach of a magnetic induction.

An electronic board was developed, its components are: CPU (Central Processing Unit), PIC16F877A, hall sensor, 16x2 LCD (Liquid Crystal Display) and the circuits responsible for system operation, such as, reset circuit, oscillator circuit with 4 MHz crystal and DC (Direct Current) power. The figure 1 shows a block diagram of the main components of the electronic board.

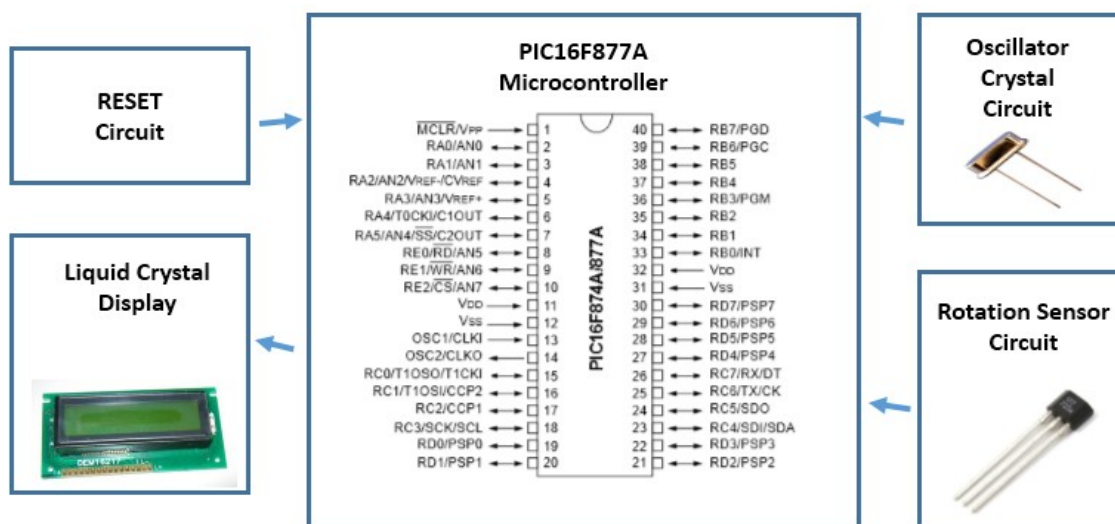


Figure 1. Block diagram of the electronic board developed.

The microcontroller programming language C was made in the software CCS Compiler (PIC-C) and the programmer of the integrated circuit was PICBurnner. The layout of the printed circuit board was developed in Eagle 4:13 and simulation testing of electronic circuits in Multisim 10.0. The figure 2 shows the microcontroller programming.

```

#include<16F877a.h>
#fuses XT,NOWDT,PUT,NOLVP
#use delay(clock=4000000)
#include<Lcd452.c>
int16 rpm=0, pulse_count=0;
void main()
{
    lcd_init();
    delay_ms(300);
    printf(lcd_write,"\f Tachometer");
    delay_ms(100);
    while(true)
    {
        set_timer1(0);
        setup_timer_1(T1_EXTERNAL|T1_DIV_BY_1);
        delay_ms(1000);
        setup_timer_1(T1_disabled);
        pulse_count = get_timer1();
        rpm = numeros_de_pulsos*60;
        printf(lcd_write,"\f ROTATION ");
        printf(lcd_write,"\nRPM    %4Lu ",rpm);
    }
}

```

Figure 2: Programming the Microcontroller.

The program developed for this project has a declaration part library, variables and startup LCD, and another main program consists of two main modules: the reading of pulsed signals by the hall sensor and another calculation module and presentation in LCD display.

The hall sensor signals are read by the pin-15 called T1CKI, timer 1 external clock, which is equivalent to pulses per second counter. Through a constant equal to 60, the speed in rpm (revolutions per minute) is submitted on the display. The figures 3 and 4 show the prototype assembly printed circuit board (Fig. 3) and Hall Effect sensor installed on the truck (figure 4).

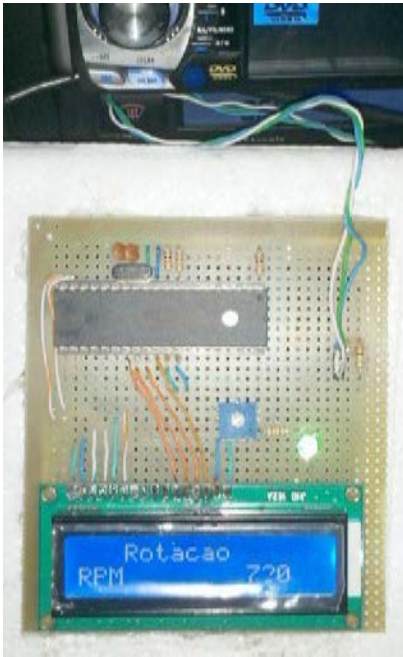


Figure 3. Prototype of the electronic circuit.

In the figure 3, you can see the CPU with PIC16F877A integrated circuit mounted on a board array of holes with copper islands, which had as interconnection component wires of 0.20 mm². You can also notice the LCD screen showing the main measure rpm.



Figure 4. Hall sensor installed on the car chassis.

The rotation sensor was fixed on the car chassis at an ideal distance so that he could receive the signal of magnetic induction of the magnet, which was fixed crankshaft pulley on the engine. When compared with values of rotation of a system commercial used by most mechanical car to monitor signs, the values were virtually the same, with a difference in measures around 10 rpm.

When compared with the result of analog rpm instrument panel cluster (car), the difference was approximately 80 rpm.

Studies are in progress in order to improve this project, such as integration of embedded systems, supervisory and CAN bus (Controller Area Network) for automotive vehicles.

3. Evaluation and analysis of results

This section discusses the evaluation plan and presents the results, which were obtained through the response to a questionnaire with 13 questions answered by the 35 students. The scope of the assessment was to determine whether certain objectives defined in the project are actually feasible. For analysis, the questions were divided into four macro-aspects of evaluation as follows:

3.1. Knowledge acquired during the interdisciplinary project developed.

In question 1, the students' perception of the knowledge acquired was an 80% in the disciplines of Materials and Automotive Components, Mechanical Design, Microcontrollers, Applied Thermodynamics, Metrology and Feedback Systems. In question 7, 73% of the students perceived the project's contribution to the knowledge from the practice of development. In question 8 students indicated a 91% discipline with greater participation in the project: Microcontrollers which corresponds to the formulation of the project.

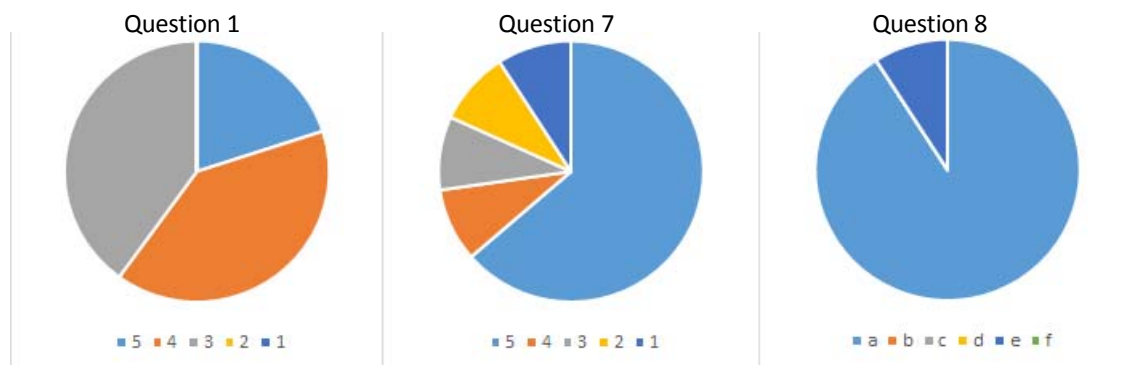


Figure 5. Results questions: 1, 7 e 8.

3.2. To evaluate the perception of multidisciplinary integrated.

In question 1, the students' perception of multidisciplinary was above 80 % , integrating the disciplines of the semester: Materials and Automotive Components, Mechanical Design, Microcontrollers, Applied Thermodynamics, Metrology and Feedback Systems.

In question 3, have been possible to identify the main disciplines studied previously and were used in the project: Electronics (37 %), Digital Systems (26 %), Calculus (8 %), Physics (7 %) and Introduction to Programming Language (22 % .) The question 8 presents the discipline of Microcontroller with greater participation in the project, and the discipline of Feedback Systems with 9 % . In question 9, 50 % of students made suggestions for incorporating higher content in the discipline Microcontrollers, 25 % indicated the discipline of Feedback Systems, 17 % Thermodynamics e 8 % Metrology. As question 1, students indicated the discipline microcontroller with greater participation in the project, but indicated this as a main discipline for project improvement, this could allow insights into more advanced topics.

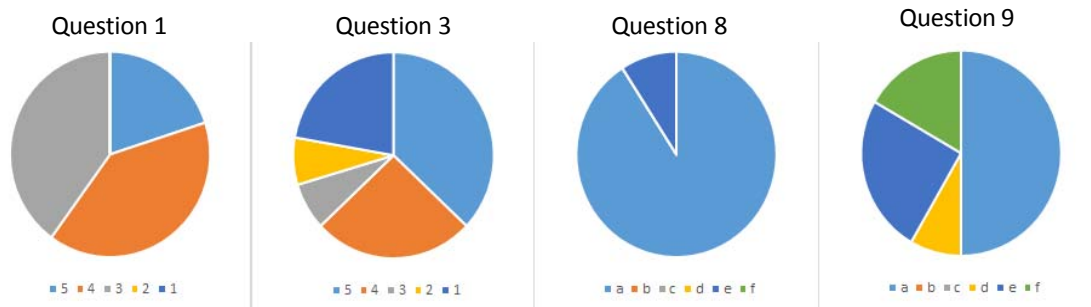


Figure 6. Results questions: 1, 3, 8 e 9.

3.3. To evaluate whether students were able to identify the prior knowledge needed and add in a more constructivist new.

In question 2, which assesses whether the concepts learned were enough to develop the project, with a results of 23% full, 54% partially and 15% knowledge that were acquired in previous semesters. Due to the practice and development of the project, the question 7 presents a 64% of the students agree that it was possible to obtain new knowledge.

As question 8, microcontrollers was the discipline with greater participation in the project. These results correspond to the objective of the project.

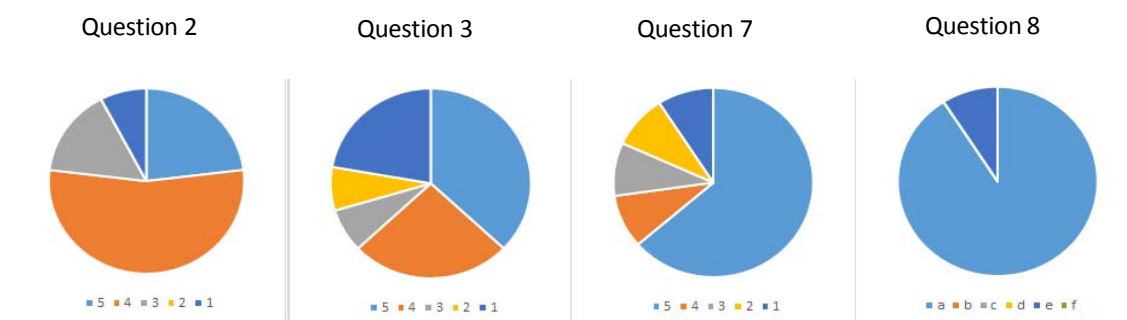


Figure 7. Results questions: 2, 3, 7 e 8.

3.4. Evaluate the application of the scientific method to solve problems.

In question 5, 82 % of students evaluated that the research conducted in the project contributed to the development. In question 6 has pointed out the mains research sources as books (16 %), internet (58 %) and teacher materials (26 %), totaling 100 %. Magazines and scientific articles were not selected. In question 10, the 80 % of respondents concluded that even without intensive research on the subject, it was possible to learn more, and perhaps, due to the project practice, understood the theoretical phenomena. The question 12 presents the project developers one analysis on future improvements to be applied as the students showed an high percentage (73 %) claim to use the regular method of "trial and error" during the project development. Importantly, in question 13 was presented some aspects of project development; being: practical application of the knowledge acquired in all subjects studied (33%), construction of a new knowledge due to the practice (25%), documentation and reporting (17%) and participatory teamwork (25%), and scientific research was not considered a factor in the realization of the project.

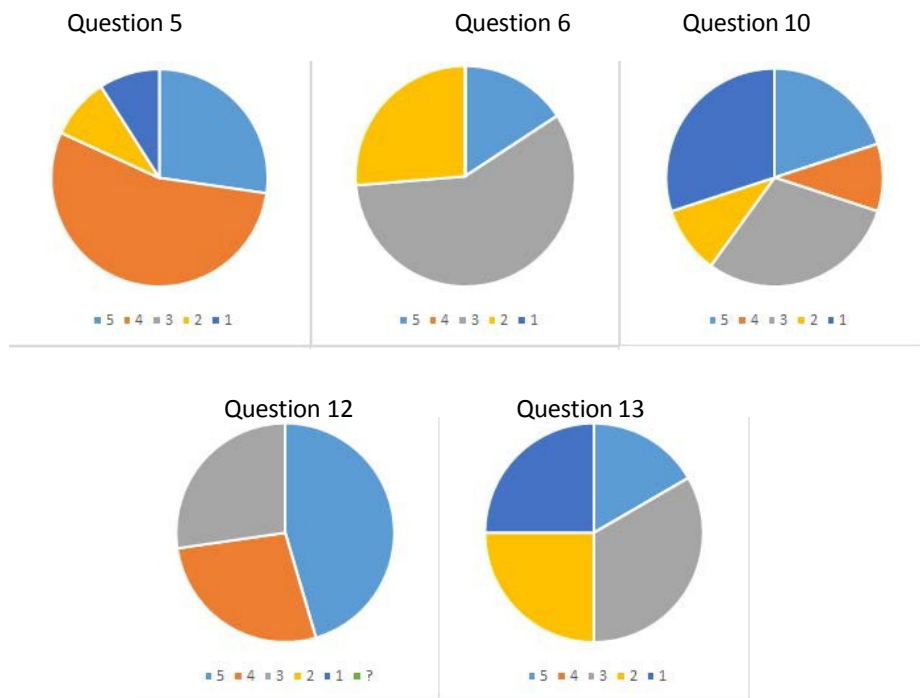


Figure 8. Results questions: 5, 6, 10, 12 e 13.

4. Conclusion

This work aimed to conduct an empirical study about the problem-based teaching and learning theories, through the elaboration of an interdisciplinary project. The main results are highlighted next: Elaboration of a multidisciplinary project plan contemplating stages according to the constructivist and situated learning theories. To direct the research, an evaluation plan was elaborated, useful for understanding and obtaining clear metrics for the study. The evaluation plan is formed by a series of questions answered by the students participating in the project. The study demonstrated that the students could identify the previous knowledge necessary to develop the project and that in a constructivist way new knowledge was acquired (total of 73%). The student perception of the multidisciplinary project was above 80%. Another important result highlighted in the evaluation is that 64% of the students agree that by the end of the project it was possible to obtain new knowledge from practice and development of the project. The students evaluated in 82% that the researches done in the project contributed to the development. It is a result for reflection, the fact that the source for research in scientific journals and articles were not selected, presenting a new objective for the next projects.

As future work, it is important to highlight the necessity of new research involving a larger number of students that reinforce the results here obtained allowing the expansion of these results to a broader spectrum within the Engineering Education.

Acknowledgments

We thank all the students of Technology in Automotive Systems, especially students: Leonardo Zacharias Pereira Filho, Mateus da Silva Marin Ribeiro e Fernando Nassi, that contributed to completion of this work.

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Active learning strategies applied to high school in Tucuruí – Pa

Patrícia M. Milhomem*, Jéssica Laina Marques e Silva*, Fabrício José B. Barros*, Wellington da S. Fonseca*.

*Universidade Federal do Pará, Campus de Tucuruí, 68464-000 Tucuruí, Brasil

Email: patricia.milhomem@tucuruui.ufpa.br, lainajessica@hotmail.com, fbarros@ufpa.br, fonseca@ufpa.br.

Abstract

Engineering is one of the oldest and most important professions in the world, and is relevant to the economic and social development of a country, hence it is observed that in the Brazilian market a great demand exists for qualified professionals in this sector, i.e., professionals able to work in teams, who have a proactive attitude in solving real-world problems. However, one of the impediments to acquiring such essential requirements for the current job market, owes to the great difficulty related to the high school in which students are not encouraged to become familiar with the exact sciences relevant to effective pursuit of engineering degrees. Thus, this article aims to demonstrate the activities developed by high school students participating in the project approved by CNPq in public announcement Title CNPq/VALE S.A No. 05/2012 - FORMA-ENGENHARIA (Graduate-Engineering), which aims to enhance teaching and learning methodology and to encourage students to pursue graduation in one of the areas of engineering.

Keywords: *Active learning, Engineering, Middle Level, Experimental Activity*

1 Introduction

Engineering is one of the oldest and most important professions in the world, and is relevant to the economic and social development of a country, hence it is observed that in the Brazilian market a great demand exists for qualified professionals in this sector, i.e., professionals able to work in teams, who have a proactive attitude in solving real-world problems, able to absorb and apply new Technologies and to develop entrepreneurial culture based on technical innovation; who have good specialized theoretical knowledge, training in research, skill in oral and written communication, innovative thinking in the course of professional life and social and environmental responsibility (Lehmann, Christensen & Thrane, 2008 and Silva, 2011). However, to acquire such essential requirements for the current job market, the process of teaching-learning should be well structured, its application being indispensable for undergraduate engineering students, nevertheless, according to Campos, Dirani and Manrique (2011) the curricula of current engineering courses in Brazil are structured so that knowledge is compartmentalized into separate disciplines, without taking duly into account the multidisciplinary training required of the engineer today. Another reason to be emphasized, owes to the great difficulty related to the high school in which students are not encouraged to become familiar with the exact sciences relevant to effective pursuit of engineering degrees (Milhomem, Bezerra, Souza, Fonseca & Barros, 2013).

Thus, for students to achieve the purpose of acting in areas that interest them and become qualified professionals for the job market, investment in the education sector by the government and federal institutions is essential to distinguish and enhance the dissemination of scientific knowledge by teachers, making classrooms dynamic from fundamental- to graduate-level courses.

Considering the aforementioned aspects that also lead to the decline of freshmen entering engineering courses and the lack of skilled engineers in the labor market, the *Laboratório de Engenhocas* (hereafter, translated: *Gadget Lab*) extension program of the Federal University of Pará (UFPA/CAMTUC), was developed during scientific activities in State Public High Schools in the municipality of Tucuruí, with a view to awaken in students an interest in engineering, using a methodology that addresses physical, chemical and mathematical concepts through the creation of experiments with reusable materials and/or of low cost, and instill in them a sense of social and environmental responsibility (Silva, 2012) e (Silva, Santos, Silva, Lima, Fonseca, & Aleixo, 2012).

To leverage this initiative, initially, interested high school students were selected to participate in the project to subsequently deploy Gadget Lab in their schools, being selected scholarship students, who would eventually serve as monitors of experimental classes. Thus, it is intended to directly encourage engineering study in each school precinct.

According to Leal (2011), the president of Capes, Jorge Almeida Guimarães, says that the problem must be nipped in the bud, that is, it is necessary to encourage learning mathematics and exact sciences from the beginning grade levels, given that students don't take the entrance exam because of physics, chemistry and mathematics.

The professional engineer usually works in various areas, such as creating projects, management, quality improvement of production systems, thus requiring basic knowledge of mathematics, physics, humanities and social sciences, along with principles and methods of analysis and of engineering design. Therefore, the project seeks to foster some skills in demand in the labor market, such as proactiveness, teamwork and public speaking among students in educational institutions.

Thus, the project demonstrates the real need to deploy Gadget Lab in the State Secondary Schools of Rui Barbosa and Ribeiro de Souza, since it is important that both teachers and students are prepared to use new teaching-learning methodologies in classrooms, thus leading to learning and encouraging the study of the exact sciences. For this it is necessary to take into account the reality of the student, the discipline to be taught, as well as the curricula that must be developed – all play a role in a big job that involves theoretical and practical studies.

In view of this, this paper aims to demonstrate the project being developed with some high school students accomplishing various training programs to improve communication skills among others, while at the same time, developing ability in the exact sciences, the methodology of teaching and learning, so as to subsequently be able to gain effectiveness in enrolling in universities.

2 Methodology

Because of the lack of trained engineers for the Brazilian labor market, the Gadget Lab Program took the initiative to intervene directly in the municipality of Tucuruí's State High Schools. According to Pimenta (2013), the laboratory aims to encourage – and not let society lose more – future scientists, engineers, teachers and even other professionals, as emphasized by program coordinator Wellington da Silva Fonseca, he being the professor at University Campus of Tucuruí and the program coordinator acting in this intervention.

As a means to directly consolidate the initiative deployed by the Gadget Lab Extension Program, recently approved by CNPq [Conselho Nacional de Desenvolvimento Científico e Tecnológico : National Counsel on Scientific and Technological Development] in public announcement Title CNPq/VALE S.A No. 05/2012 - FORMA-ENGENHARIA (hereafter translated: Graduate-Engineering) and through partnership with the 16th URE (Regional Teaching Unit), responsible for all state schools in Tucuruí and its surrounds, it was possible to place a team of students at Rui Barbosa and Ribeiro de Souza, being the main public schools with the largest number of students enrolled.

Approval of the Graduate-Engineering Project by CNPq enabled these students to begin to receive scientific initiation scholarships, making possible the enrichment of their curriculum, and familiarizing them with scientific and technological projects. Scholarship students currently part of the project were nominated by teachers at their schools and selected through a workshop conducted by members of the Gadget Lab, where a good deal of existing physics experiments had been developed and studied in the laboratory. In the workshop, several criteria were analyzed such as: ability to develop activities as a group, communication skills, affinity for exact sciences and especially proactiveness and interest in participating in the project. At the end of the workshop, the students presented an experiment, it being possible to analyze their skills individually, as demonstrated by Figure (1).



Figure 1 - Experiments presented in the selection

After defining the teams, currently composed of seven scholarship students and three volunteers at Rui Barbosa, and five scholarship students at Ribeiro de Souza, the next step was the development of scientific papers on the experiment presented, as well as others already at the laboratory. The papers went through a number of revisions by the program staff, then made available on the Gadget Lab website, which can be accessed at www.labengenhocas.ufpa.br. At this stage, it was recognized that the scholars had trouble writing, needing guidance and short courses on scientific essays and acclimation to the use of computational tools, aiming initially, to hone handwriting and spelling. So during the project various reports are being developed simultaneously to encourage the habit of reading.

Since the establishment of the teams, it was decided that the scholars should go through all the projects developed by the Gadget Lab Extension Program of University Campus of Tucuruí (CAMTUC), these being: Engenhatube Camtuc, Jogoteca Tucunaré, Introduction to Superconductivity and Nanotechnology, Science Fair and Introduction to Robotics.

The first project to have scholar activity was Engenhatube. The students recorded and edited audiovisual media of the experiments that they developed and then put them on the Gadget Lab website and its YouTube portal, called *Engenhatube Camtuc*. The Engenhatube project concerns sharing the knowledge gained at the university, and even in projects conducted by high school students, for the dissemination of science and technology in the Amazon region, since it is necessary to implement attractive alternative teaching and learning, since students are more motivated by Information and Communications Technologies (ICT) and less motivated by traditional teaching methods, thereby making them proactive in the quest for knowledge.

While completing these activities, the scholars received lectures on Nanotechnology and Superconductivity, taught by undergraduates of the Electrical Engineering Scholar Program (Figure 2). The project aims to spread this modern science in secondary schools and therefore, in the city population.



Figure 2 - Lecture on Nanotechnology and Superconductivity

Recently, the scholars were involved in the *Jogoteca Tucunaré* project of the Gadget Lab, in which they had the opportunity to develop (Figure 03) and present educational games that awaken skills in logical reasoning and basic operations in children and adolescents at an elementary school.



Figura 3 - Making games for the Jogoteca Tucunaré Project

Of course, students could not help but make playful and interactive presentations using experiments of physics and chemistry from alternative and low cost materials, since this is the essential nature of the program as mentioned by (Milhomem, Souza Bezerra, Fonseca & Barros, 2013). Thus, they presented the projects they developed during the workshop to teachers in Breu Branco, a municipality near Tucuruí, showing them the methodology they, as students, would like to see developed in the classroom, as illustrated in (Figure 4). It is evident that students are encouraged in the pursuit of physical and chemical knowledge through experiments presented by the teacher in a more dynamic form.



Figure 4 - Presentation to teachers in Breu Branco

Besides presenting to teachers in the municipality of Breu Branco, the high school students had the opportunity to actively participate in training workshops conducted by the Gadget Lab for "newbies" to Electrical Engineering, Civil Engineering, Mechanical Engineering and Pedagogy at UFPA/CAMTUC.

The next step developed was organizing the 2nd Science Fair of State Schools of Tucuruí, whose theme is Technological Innovation and Sustainability. To encourage them, the students themselves who are part of the Gadget Lab Project in high schools, scholars of the Junior Scientific Initiation and scholars of the Industrial Technology Initiation, along with the students of UFPA – CAMTUC were responsible for presenting the Science Fair project to more than 60 high school classes. The same happened at Rui Barbosa, Ana Pontes, Simão Jacinto dos Reis and Raimundo Ribeiro de Souza. One of the presentations is shown in (Figure 5).



Figure 5 - Publicizing the Science Fair at Ribeiro de Souza High School

At the Fair, scholars of the Graduate-Engineering program had the opportunity to present the work that they are developing with alternative materials such as a low-cost filter to be deployed in homes not served by the water treatment plant in the municipality of Tucuruí (Figure 6). As well, they made presentations with Arduino and Lego Robots provided by the Gadget Laboratory Program.



Figure 6 - Presentation of the low-cost filter at the Science Fair

The 2nd Science Fair has resulted in affiliation with FEBRACE 12 (Brazilian Science and Engineering Fair), earning a finalist spot for the project and submitting three projects directly for individual selection.

Another activity being developed is construction of a solar water heater for a residence of six people, using post-consumer packaging: 300 PET bottles and 300 Tetra Pak juice cartons, i.e. 50 each per person. They derived the required dimensions of 7.6 meters, shown in Figure (6).



Figure 7- 7.60m Solar Heater panel

3 Results

Since the project began in January 2013, several activities have been carried out in order to motivate scholars in fundamental disciplines of an engineering course, such as mathematics, physics and chemistry. This motivation was mainly through the development of projects that use alternative materials, as well as proximity to and interaction with the university. One example is the solar heater because it has contributed to improving the knowledge of the students involved, since the theoretical information accumulated during classes becomes assimilated and is put into practice with physical phenomena occurring for the proper functioning of the Solar Panel, thus, reinforcing and facilitating learning in the disciplines of the exact sciences, and encouraging them to seek knowledge and education in these areas.

Beyond being motivated to choose an area that engineering offers, the project seeks to develop and awaken the scholarship students as soon as possible, to the skills required of an engineer in the labor market, including teamwork, communication, environmental awareness and proactivity. As, according to Lehmann et al. (2008), engineers currently

are expected to master a combination of different skills, not limited only to technical competence in problem solving, production and technological innovation, but also including interdisciplinary skills of cooperation, communication, management of continued learning in diverse cultural and social environments, with innovative thinking throughout their professional careers.

For the record, a debate was held with the scholars regarding the progress of the project, its influence on their professional careers, the skills they developed and acquired so far, and how they would like lessons in physics, chemistry and mathematics to be taught in their schools beyond their opinions about the roles of the teacher and the student. The debate was surprising. The students expressed appreciation for the opportunity granted, others reported that before participating in the project, they had not considered taking the college entrance exams, but after completing a few activities and getting accustomed to the university environment, began to plan and devote most of their time to study, in order to obtain good results in the entrance exam.

Others emphasized their development in communication with the public, that they now present schoolwork with more confidence and determination. They also commented that by participating in the Graduate-Engineering Project changed their thinking and decided that engineering is the career they now want to pursue. Currently, 98% have decided that they cannot imagine working in an area outside one of the branches of engineering: Civil, Electrical, Mechanical and Robotics Engineering.

Meanwhile, the comment unanimously emphasized was in reference to the classes of exact sciences. Everyone argued for the importance of linking theory with practice, since in this way there will be motivation and dedication on the part of the students in learning science in general. Others were further ahead in reporting that practical experience facilitates the understanding of everyday physical and chemical phenomena. In addition, this makes the lessons more enjoyable, since experiments can be presented playfully.

It is noteworthy that this enables the development of research skills and proactivity in the students, as they become responsible for seeking knowledge of the concepts involved in their projects, in resources available on school grounds, e.g. books in the school library, the computer lab with internet access, as well as those of the city itself: the central library and digital inclusion center.

In view of this, we intend to continue to encourage students to study engineering, since scholars in state high schools work actively in the multidisciplinary laboratory at their schools, where it can be analyzed that even in those that have laboratories, they are an underutilized space, and with the activation of the lab, teachers can be given the opportunity to improve their teaching and other professional activities, as developing experiments is also important for students.

Thus, a joint reflection is needed on these issues and on the search for alternatives that enable greater effectiveness of activities developed in laboratories, taking into account their feasibility within the scope required under the PPI (Institutional Politico-Pedagogy) Project.

4 Conclusion

It is noticeable that one of the major difficulties currently in elementary and high school is not merely to realize applications and different methodologies, but also, to get the student apprentice involved in curricular activities. Many students when they encounter difficulties in the subjects, especially exact sciences, cannot continue in higher education or even complete basic education.

From this perspective the aim of the study was to demonstrate the Gadget Lab outreach program's initiative jointly with teachers in state schools in the city and how it aims to foster in students the desire to get the top level in an engineering course. Altogether, the Graduate-Engineering project is not limited only to encouraging them to pursue engineering areas, it also proposes to show educators and teaching staff at each school precinct that it is possible to make classes in physics, chemistry and mathematics more attractive, and thus awaken students to the quest for knowledge and to the importance of technological areas. To do so, it has the primary objective of enabling existing multidisciplinary laboratories in these schools, developing science experiments with alternative and low cost materials to every teacher's classroom, and at the same time, bringing them closer to the University.

Acknowledgements

The group involved in this work appreciates the collaboration between UFPA and the Eletrobrás/Eletronorte enterprise for their constant support for projects at Tucuruí Campus. Also we extend gratitude to Vale, CNPq and

Sophos College for project collaboration in the Graduate-Engineering project and Science Fair. Many thanks also to Joseph Bernard Shirk, professor of English, for the technical translation.

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Engineering programs in the areas of Oil & Gas, Petrochemicals and Biofuels: raising the interest of high school students in related courses.

Michele R. A. Z. de Souza*, Andressa M. da Costa*, Bruno C Menestrino*, Bruno R. Machado*, Gustavo Porciúncula*, Jéssica Baranzelli*, Juliana F. Teixeira*, Juliana Zilli*, Nicole Luconi*, Pedro M. Melo*, Willian R. Rocha*, Renata K. F. Borges*, Jorge A. V. Costa*

*Universidade Federal do Rio Grande, Rio Grande do Sul, Brazil

Email: michrandrade@gmail.com, dessa.maio@hotmail.com, bmenestrino@gmail.com, brunoroswag@gmail.com, porciunculag@yahoo.com.br, jesyka180@hotmail.com, juliana_teixeira1990@hotmail.com, jgzilli@hotmail.com, nicoleluconi@hotmail.com, pedromotta6@hotmail.com, willianrosarg@hotmail.com, jorgealbertovc@terra.com.br

Abstract

The increase in demand for professionals in the fields of Oil & Gas, Petrochemicals and Biofuels, are strongly associated with the technological development of the country. In contrast, the low performance of high school students in natural and exact sciences is a matter of concern, which may have negative influence on the choices for undergraduate courses in these areas, especially in engineering. In undergraduate courses, high rates of repetition and dropout have motivated studies and some actions to reduce this. Both mentioned problems can be addressed already in high school looking to increase the interest of students in subjects in the field of exact sciences and clarifying what the engineering courses are. In this context, encouraging the interest in the exact and natural sciences in high school may contribute to the increased demand for engineering courses, particularly in these strategic areas. Some actions in this regard are presented in this paper.

Keywords: biochemical engineering in high school, exact and natural sciences; workshops

1 Introduction

The technological fields of Oil & Gas, Petrochemicals and Biofuels are strongly associated with the technological development of the country. According to the National Petroleum Agency, Natural Gas and Biofuels energy consumption in Brazil grew at a rate of 4.9 % per year over the last 30 years. The total demand for petroleum products in 2001 was 107million m³ p.a. Diesel and gasoline accounted for 56% of consumption in volume. LPG, naphtha and fuel oil accounted for another 32%. The southeast region concentrated almost half of the total volume (47%) followed by the southern region (21 %) and Northeast (18 %). The other regions accounted for 14%.

The demand for engineers in Brazil surpasses the supply of these professionals. According to the Federal Council of Engineering and Agronomy, Brazil graduates about 40,000 engineers per year, while Russia, India and China form 190000, 220000 and 650000 engineers per year, respectively.

Considering the student as an active element in the learning process, methodologies that seek to enter him in this process should be adopted. Science education should provide all students the opportunity to develop skills that arouse in them the uneasiness of the unknown, seeking logical and reasonable explanations, leading students to develop critical positions, make judgments and decisions backed by tangible elements (Bizzo, 2009).

According to Bizzo (2009) "The school [...] knows very well what goals there are to find, but discussions of how to reach them point in different ways." Much of the research developed their formulations, criticisms and proposals from the premise that education should be directed to the formation of a full citizen, ie, for an individual who can participate actively and consciously in his social context (Caetanoa and Linsingenb, 2012).

Nevertheless, the reality in schools shows that disinterest still in high school, mainly in disciplines of the natural and exact sciences, is not a new issue. This is one of the reasons why young people opt for other areas when choosing their careers. Another fact which hinders reaching the demand for engineering professionals in the fields of Oil & Gas, Petrochemicals and Biofuels is the high dropout and failure rates of those enrolled in these courses. In 2007, FURG joined the Support Program REUNI (Programa de Apoio a Planos de Reestruturação e Expansão das

Universidades Federais – REUNI), recognizing as factors that contribute to evasion in undergraduate courses: inadequate teaching and pedagogical practices, socio-economic status of the student, lack of knowledge, especially in key areas, personal reasons and little expectation and student interest on the vocational training chosen.

In the field of evasion, several studies have been conducted, and several initiatives have been put into practice in public and private institutions (Silva et al., 2006). The admission of students without the knowledge of what really are the courses and subjects studied and the labor market is another reason that can lead to disinterest and result in evasion. Accordingly, Simple initiatives such as take undergraduate courses in engineering to the High Schools, show job opportunities, clarify to high school students about the courses, can contribute to the solution of these problems.

The job market for professionals in the fields of Oil & Gas, Petrochemicals and Biofuels, currently expanding in Brazil, is another incentive to the youth in opting for Engineering, especially in cities like Rio Grande, home of the Federal University of Rio Grande, in which a naval industry was recently installed, moving the local economy and bringing diverse job opportunities.

Understanding the exact and natural sciences through the study of natural phenomena and current facts involved in the production and use of oil, petrochemicals and biofuels can make teaching exact and natural sciences more attractive and accessible to high school students, besides awakening their interest in those sciences. The interaction of engineering and high school can be a channel that promotes connections between the basic teachings of the exact sciences, and can steer a greater number of young people to these areas.

Aiming to increase the supply of trained professionals in the fields of Oil & Gas, Petrochemicals and Biofuels, government programs like MCT/FINEP/CT- PETRO - PROMOPETRO 02/2009, are making this issue its focus. At the Federal University of Rio Grande - FURG, under the PROMOPETRO, the INTERPETRO project of Integration for Development Areas in Oil & Gas, Petrochemicals and Biofuels - FURG and The High Schools is being developed. The goal of the developed activities is to awaken vocations to the professions of Oil & Gas, Petrochemicals and Biofuels. As specific objectives, the project aims to promote the interaction of engineering courses at FURG with Public and Private High Schools in Rio Grande - RS in the exact and natural sciences activities in Oil & Gas, Petrochemicals and Biofuels context; awakening the interest of high school students in the disciplines of Chemistry, Physics, Mathematics, Biology and Informatics, and empower high school students to identify needs and opportunities for professionals in the fields of Oil & Gas, Petrochemicals and Biofuels, encouraging critical sense and highlighting the social, environmental and economic role of the professional.

The project includes the participation of 8 undergraduate courses at FURG and in this context, the undergraduate program in Biochemical Engineering participates with the sub - project: The Biochemical Engineering in Oil, Gas, Petrochemical and Biofuels context. The undergraduate degree in Biochemical Engineering at the Federal University of Rio Grande - FURG is offered since 2010, being one of the few in Brazil (<http://emec.mec.gov.br/>). The profession of a Biochemical Engineer is sometimes mistaken by freshmen with others, such as Biomedical or Pharmaceutical (unpublished data from a survey of freshmen). The Levels of evasion in courses such as Food Engineering (16.35%), Biochemical Engineering (12.82%) and Chemical Engineering (9.27%), regardless of retention in the interval between 2008-2012 (except for Biochemical Engineering, considering the range of course creation from 2010 to 2012) were, on average, higher than the overall dropout rate in FURG (11.21%).

Thus, integrating the course of Biochemical Engineering in joint activities with high schools in the context of Oil, Gas, Petrochemical and Biofuels is an opportunity to awaken the interest of high school students on the theme and also in the new undergraduate course at FURG as well as capture more well prepared students for the course.

Through this Promoted interaction, an increase is expected to be seen in the coming years in the interest of high school students from Rio Grande for the disciplines of exact and natural sciences and vocations in the context of Oil, Gas, Petrochemical and Biofuels are aroused. Moreover, the offer and the characteristics of the course of Biochemical Engineering is expected to be clarified to future freshmen, in order to decrease dropout rates and retention, especially those due to the lack of knowledge on the part of incoming students.

2 Objective

The objective of this work is to present and discuss the activities carried out under the sub - project " Biochemical Engineering in the context of Oil, Gas, Petrochemical and Biofuels ", which is promoted by the interaction between Biochemical Engineering of the Federal University of Rio Grande - FURG with private and public schools in the municipality of Rio Grande - RS, Brazil.

3 Development

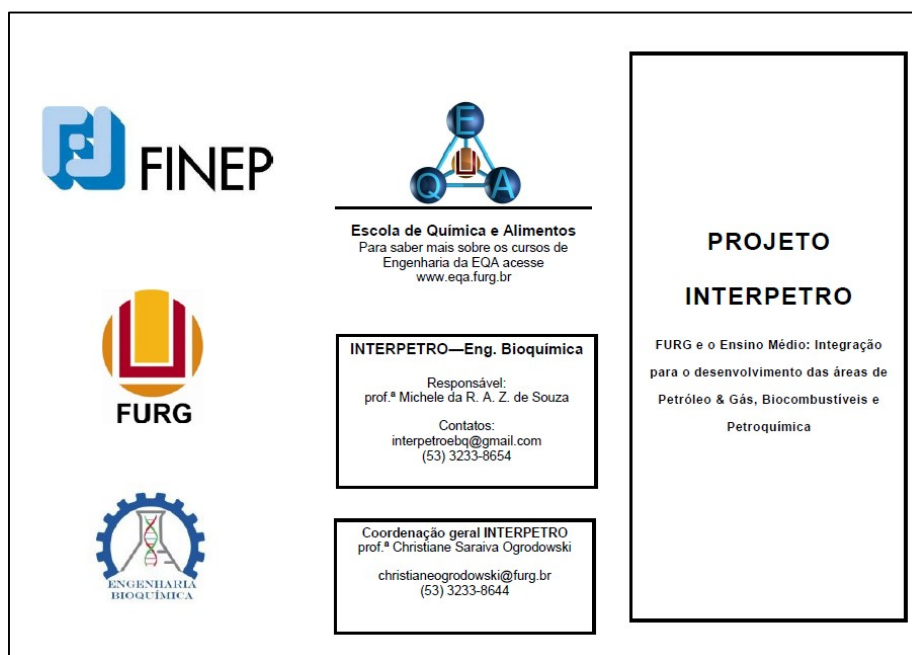
Activities of the Biochemical Engineering in the context of Oil, Gas, Petrochemical and Biofuels Project" are conducted on exact and natural sciences, relating the Oil & Gas context, Petrochemicals and Biofuels, seeking to awaken the interest of high school students in the disciplines of chemistry, physics, mathematics, biology and computer science and Thus for professions that require such aptitude. Below, the strategies being employed are described and discussed.

3.1 Work Team

The team of the sub - project consists of 11 graduate students in Biochemical Engineering, with 7 freshmen (students in their first semester). 1 of these is a volunteer and the others are scholarship recipients; 6 students in masters or doctoral in the Engineering and Food Science Graduate program with thesis work or dissertation related to Oil & Gas, Petrochemicals and Biofuels context, and 6 teachers of Biochemical Engineering courses. The target audience was Teachers and high school students from public and private schools of the city of Rio Grande - RS, Brazil.

3.2 Dissemination of the project and mobilize the audience

Promotional material was prepared including a folder (Figure1) and a list of workshops available (Table1). The dissemination of the project was carried out via email to all schools spanning the 18th Regional Coordination of Education and also in person by the project team in events that brought together teachers and principals of high schools. Dissemination activities are performed by fellows and coordinated by the teacher responsible for the sub - project.



Projeto INTERPETRO	Subprojeto INTERPETRO Engenharia Bioquímica	Como posso trazer o INTERPETRO para minha Escola?
<p>Objetivos</p> <p>⇒ Promover a interação dos cursos de Engenharia da FURG com Escolas Privadas e Públicas de Ensino Médio de Rio Grande, abordando o assunto "Petróleo & Gás, Biocombustíveis e Petroquímica".</p> <p>⇒ Despertar o interesse dos estudantes de ensino médio pelas disciplinas de Química, Física, Matemática, Biologia e Informática.</p> <p>⇒ Despertar vocações para as profissões das áreas de Petróleo & Gás, Biocombustíveis e Petroquímica.</p> <p>Como alcançaremos esses objetivos? Através da realização de oficinas nas Escolas, visitas a laboratórios da FURG e disponibilização de material didático.</p> <p>Serão 7 cursos da FURG oferecendo estas atividades. Um deles é o curso de Engenharia Bioquímica.</p>	<p>O curso de graduação em Engenharia Bioquímica iniciou em 2010 na Universidade Federal do Rio Grande – FURG. É um curso que proporciona sólida base de conhecimentos de Engenharia aliada aos processos celulares e biológicos. A Engenharia Bioquímica está presente no contexto "Petróleo & Gás, Biocombustíveis e Petroquímica" principalmente na produção de diversos biocombustíveis, no tratamento de efluentes, na biofixação de CO₂ e na biorremediação de ambientes contaminados.</p> <p>Para ler mais sobre o curso de Engenharia Bioquímica acesse www.engbioquimica.furg.br</p>	<p>Entre em contato com a equipe do INTERPETRO para agendarmos oficinas na sua Escola e/ou visitas orientadas a laboratórios e projetos da FURG.</p> <p>Se sua escola tem feira de profissões, palestras para os estudantes, ou eventos semelhantes, convida a equipe do INTERPETRO - Engenharia Bioquímica para participar.</p> <p>Subprojeto INTERPETRO - Eng. Bioquímica</p> <p>Contato: fone 3233-8654 / 3233-8644</p> <p>Responsável prof.ª Michele da R. A. Z. de Souza</p> <p>E-mail: interpetroebg@gmail.com</p>

Figure 1: Folder of the sub - project "Biochemical Engineering in Oil, Gas, Petrochemical and Biofuels context" in high schools.

3.3 Mapping the interest of high school students

All high school students participating in the project account through a questionnaire through which information on the number of professions interested in following technological areas of oil, gas, petrochemical and biofuels. The knowledge the students have on courses, occupations, and market activities in these areas will be assessed. The questionnaires will outline the profile of students and detect any possible relationship between the choice of a college degree and other variables such as performance on exact sciences and the occupation of parents. The next freshmen in the course of Biochemical Engineering will be monitored in order to detect students who participated in the INTERPETRO project. The questionnaires include the following questions;

1. School:

2.Serie

3. Age:

4.Sex :

() Female

() Female

5.Do you work:

() Yes

() No

6. Educational level of the father:

() Incomplete elementary school

() Complete elementary school

() Incomplete High school

() Complete High school

() Incomplete Graduate

() Graduated

() Post Graduate

7. Educational level of the mother :

- ☐ Incomplete elementary school
- ☐ Complete elementary school
- ☐ Incomplete High school
- ☐ Complete High school
- ☐ Incomplete Graduate
- ☐ Graduated
- ☐ Post Graduate

8. Occupation of father:

9. Occupation of mother:

10. Will you do ENEM this year?

- ☐ Yes
- ☐ No

11. In which of these areas do you most identify?

- ☐ Humanities (eg history, geography, psychology and education)
- ☐ Exact (eg, engineering, accounting, administration...)
- ☐ Exact and earth sciences (eg mathematics, engineering, and physics)
- ☐ Health sciences (eg, medicine, physical education and nursing)
- ☐ Life sciences (e.g. biology)
- ☐ Language, literature and arts (eg, visual arts and letters)
- ☐ Applied social sciences (eg, law, business, library science, economics)

12. What prompted the choice of this area?

- ☐ Remuneration
- ☐ I have a vocation
- ☐ Professional Status
- ☐ Low competition on University Entry
- ☐ Others. Which?

13. Do you know what the Biochemical Engineer does?

- ☐ Yes
- ☐ No

14. What does the Biochemical Engineer do?

15. If you had to choose between engineering courses, which of these would you choose.

- ☐ Biochemical Engineering
- ☐ Civil Engineering
- ☐ Civil Engineering Coastal and Port
- ☐ Civil Engineering Business
- ☐ Food Engineering
- ☐ Automation Engineering

- ☐ Computer Engineering
 - ☐ Mechanical Engineering
 - ☐ Mechanical Engineering Business
 - ☐ Mechanical Engineering Naval
 - ☐ Chemical Engineering
 - ☐ Other.Which ?
16. If you chose Engineering, why?
- ☐ High remuneration
 - ☐ I have a vocation
 - ☐ Professional status
 - ☐ Low competition for University entry
 - ☐ High employment perspective
 - ☐ The course is very easy
 - ☐ Other. Which?
17. If you do not chose Engineering, why?
- ☐ Low pay
 - ☐ I have no vocation
 - ☐ Low professional status
 - ☐ High competition on University entry
 - ☐ Lack of job prospects
 - ☐ The course is very difficult
 - ☐ Other.Which ?
21. What subjects do you like best ?
22. What subjects do you like least ?

4 Conducting Workshops

The workshops offered by the course staff associate Biochemical Engineering in Oil & gas, petrochemical and biofuels context, addressing mainly the production of biofuels, environmental issues such as global warming and bioremediation of contaminated environments, including oil spill, substitution of products of petrochemical origin such as plastics with biodegradable products. A brief description of the workshops in high schools is presented in Table 1.

The workshops are taught by professors of Biochemical Engineering or Engineering students of the Graduate Program in Engineering and Food Science, to develop their dissertation or thesis research on issues related to the project. During the workshops, students are constantly challenged in order to encourage their participation in the workshop and interest in the topic, drawing on the personal experience of each.

Before each workshop, undergraduate students in the project talk informally with High School students about the course of Biochemical Engineering, talk about the reasons that led them to choose to join Biochemical Engineering, the difficulties they faced in the start of the course, among other topics, in an accessible language and familiar to students of high school.

During the workshops, the speaker highlights the importance of technological careers in the Oil & Gas, Petrochemicals and Biofuels for the development of the country, mainly in the energy sector and the environment. Some problems of economic and environmental concerns that are on the agenda in the media and their relationship to engineering and the role of youth in the country's future are raised.

Table 1 : Workshops offered by the Biochemical Engineering team to High Schools through the sub - project " Biochemical Engineering in the Oil, Gas, Petrochemicals and Biofuels context."

Workshop	Description
Biochemical Engineering	During the workshop the course of Biochemical Engineering and opportunities in this area are discussed in a simple way, through various products on the daily lives of students and their families, such as wine, beer, yogurt, antibiotics and alcohol fuel. Disciplines and activities that make up the course of FURG, research projects in progress, the job market and career opportunities are discussed.
Microalgae	In this workshop the topics covered are: what are microalgae, ways of obtaining microalgal biomass, forms of cultivation and bioreactor, biomass applications and also Microalgae x Energy and Biofuels relationship. Topics of Biology and Chemistry are featured in the context of the production of microalgalbiomass.
Bioremediation	Bioremediation is an environmental remediation technique that uses microorganisms to degrade pollutants compounds and can be used when environmental accidents such as oil spills at sea or land occurs. In this workshop, simple experiments of action of surfactants in oil spill in water are carried out and raised the basic principles of chemistry.
Greenhouse effect and CO ₂ fixation	The workshop focuses on the greenhouse effect, global warming, its causes and consequences, and alternatives in the context of engineering in order to reduce greenhouse gas emissions, among them the cultivation of microalgae, intensively studied in FURG.
Benefits of microorganisms to humans	Micro-organisms are the causative agents of many human pathologies, but they may also be beneficial or essential for the maintenance of life on earth. They may have a central role in the production of enzymes and drugs, in the food industry, the chemical recycling of waste and degradation of pollutants. In this workshop, students are continually challenged and encouraged to think about the micro-organisms and their potential, especially raising questions in the context of biology.
Biogas	The process of biogas production is explored, the potential of waste in energy production, biogas applications as an alternative energy source and comparing this to other biofuels, highlighting the role of engineering in power generation and environmental protection.
Plastic Biodegradable	The workshop addresses the impact of the accumulation of plastics in the environment, and the use of renewable raw materials for production of biodegradable plastics.
Nanotechnology	In the nanotechnology workshop addresses the concept of nanotechnology, nanomaterials applications in everyday life. To make a counterpoint to the benefits, issues that involve the risk that this technology can lead to man and the environment are questioned.
Biopolymers	Biopolymers are plastic materials produced from micro -organisms. These materials exhibit biodegradability in 3-12 months when discarded into the environment, causing less environmental problems than plastics have that take years to degrade. This workshop is to explore the possibility of replacing Biochemical Engineering products with others of petrochemical origin.

5 Results obtained in carrying out the work and future prospects

Vocations awakened in students of high schools participating in the project will be quantified in the medium term, after the detection of the students participating in the project and who joined engineering courses at FURG, particularly in the course of Biochemical Engineering.

To date, four months after the dissemination activities of the project, 3 high schools have shown interest in joining the volunteer project and are being addressed within the workshops. Close contacts for divulgation will be made in person by the project team in schools, to mobilize greater number of teachers and principals to participate.

The experience to date with the completion of this work allows us to highlight the importance of including freshmen students in project activities at the High School. The development of activities also brings benefitsto these students,

such as increased integration of students with higher grades of the course, with graduate students and teachers, besides the increase of knowledge and interaction with the entrants in the Biochemical Engineering course.

Another positive result that may already be listed with the development of the project is the experience gained by graduate students in Extension activities with high schools during the workshops. Although this type of activity is part of the triad of the University, it is unusual in most graduate programs.

6 Acknowledgement

The project team thanks the participant Schools so far: Silva Gama State High School, Marechal Mascarenhas de Moraes State High School and Getúlio Vargas Technical School.

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Web Collaboration in Microelectronics Education: Techniques and Challenges

Carlos Alberto Rosa¹, Wilhelmus Adrianus Maria Van Noije²

^{1,2}Department of Electronic Systems Engineering (PSI), Polytechnic School of Engineering, University of Sao Paulo (EPUSP)
São Paulo, Brazil

Email: prof@carlos-rosa.com, noije@lsi.usp.br

Abstract

This paper presents contributions in engineering education for thematic discussion on Microelectronics Education (microEDUC) in Brazil. The development of microEDUC platform was realized from research in the field of CSCW (Computer-Supported Cooperative Work) and CSCL (Computer-Supported Collaborative Learning). The microEDUC platform uses emerging technologies for web-based applications and mobile devices such as: Web-based Collaboration (WbC) and Cloud-based Collaboration (CbC). The collaborative model used in microEDUC platform, the resources and cloud technologies are presented. The microEDUC platform was modelled as an experimental virtual platform focused on the development of teaching practices and active learning strategies, integrating cooperative learning and collaborative learning with mobile learning (m-Learning). The microEDUC platform integrates Web and Cloud technologies of collaboration tools using Web browsers apps and social media as blogs, wikis, social networks, media sharing platform. Cloud storage like Dropbox, Google Drive, iCloud, SkyDrive and others as new way to use cloud collaboration with collaborative tools based on mobile devices. The microEDUC platform as a web-based infrastructure is being used by professors and researchers working in Microelectronics Education to share knowledge, teaching practices and experiences producing audio and video contents and others materials useful for flipped classroom. At same time, students can be encouraged to realize your assignments and share them with your local workgroups, or students from other locations or countries.

Keywords: Active learning, m-Learning; Flipped Classroom; Collaboration Learning; Web Collaboration; Cloud Collaboration; CSCL; CSCW; OCW; MOOC; VLE; Virtual Learning Environment; microEDUC; Microelectronics Education; Engineering Education.

1 Introduction

The goal of active learning, according to Wurdinger & Carlson (2010), is to promote students participation and interaction in the classroom. Many strategies can be approached by teachers to provide to students a experiential learning, for instance: active learning, problem-based learning, project-based learning, service-learning, place-based learning, experiential education, action learning, adventure learning, free-choice learning, inquiry-based learning, cooperative learning and collaborative learning.

According to Weber (2004), "Cooperative and collaborative learning differ from traditional teaching approaches because students work together rather than compete with each other individually". Cooperative learning is a specific type of collaborative learning. When groups of students meet to discuss how the presentation of a work will be taken, or when students from different schools work together via the Internet are involved in a collaborative learning process.

For instance, if a student distributes their individual works with other students, lending his paper notations or using electronic technologies (sending attachments by e-mail, posting on media websites, sharing PDF files, Word documents, PowerPoint presentations, audio podcasts or videos, etc), are involved into study field of collaborative learning.

In cooperative learning the students work in small groups to complete a structured activity. Individually are assessed for their works, for their individual collaboration in the results of workgroup as a whole. In cooperative or collaborative groups the students are encouraged to work face-to-face to achieve greater interaction of teamwork. The individual performance of a member and the quality of your interpersonal interactions can be evaluated individually between them. After that the evaluation is sent to the professor to compose the final grade for each assignment.

1.1 Microelectronics Education

Noting the history of mankind we may say that never a unique technology developed by man was able to promote changes in the lives of so many people as happened with electronic technology, with only a century of existence. Throughout the twentieth century, have developed the main physical theories of the constitution of matter and energy, chemical and biochemical theories, theories of information and computation, economic theories, social theories and in other applied sciences.

The sharing of scientific knowledge was intensifying among the people, to the extent that new information and communication technologies were emerging and internationally popularizing along with the phenomenon of globalization. According to Knapp (2007, p. 15), Milton Friedman, Nobel Prize in economics in 1976, explained the phenomenon of globalization with the following famous words: "it is possible to produce a product anywhere, using resources from anywhere, by a company located anywhere, to be sold anywhere".

Scientific knowledge of the twentieth century were key to the invention of various instruments, machines, equipment and devices that guided the creation of new methods and processes that have transformed our natural material world. New synthetic materials were invented and revolutionized our industry and society. Production methods with high level of quality on a large scale were developed for factories to process new products quickly and deliver them promptly to global market.

With the significant development of satellite telecommunications, telephony and mobile computing, the world has become increasingly globalized. With the popularity of smartphones and tablets began to have the feeling that the world was small, and everything in it now rests in our hands.

Looking for inventions of the twentieth century, we can say the first half of the century was marked by inventions that have expanded human knowledge through the study of phenomena in micrometer scales, microanalysis techniques and optical microscopy. And the second half of the century was marked by inventions that increased scientific knowledge about phenomena in nanometer scales through scanning electron microscopy (SEM), atomic force microscopy (AFM), and scanning tunneling microscopy (STM).

The consumer electronics devices sold nowadays have become so complex, and to design them or manufacturing them involves the knowledge of many disciplines, it is virtually impossible to design a curriculum for engineering courses electronic systems to cover all aspects involved. A priori, in Brazil, the curricula of engineering courses are designed to provide the student with a general education within five years. And the curricula of technological courses are designed for more specialized training, short-term, ranging between two and three years.

There are numerous scientific and technological achievements that have contributed to the development of microelectronics until the current state of the art of nanotechnology and nanoelectronics.

In the area of manufacturing processes, include:

- 1) Use of high-precision techniques for pattern transfer by photolithography at the nanoscale (Nanolithography);
- 2) Use of techniques for batch processing of silicon wafers;
- 3) superficial cleaning processes contaminants from silicon wafers (RCA clean);
- 4) Use distilled and deionized water with high purity and decontamination;
- 5) Use of ultra-high purity chemicals, impurity-free;
- 6) Using processes of chemical reactions by dry plasma ultra controlled (CVD - Chemical vapor depositions and PE-CVDs using plasma technology);
- 7) Use of clean rooms with high degree of cleanliness (Class 100 - one hundred particles with dimensions of 500 nm per cubic foot of air);
- 8) Use of advanced technique simulators on manufacturing processes and management (CAM - Computer Aided Manufacturing).
- 9) Use of automated manufacturing processes and robotics to ensure maximum repeatability of processes and minimal variability tolerance of fabrication parameters within specifications and electrical characteristics determined in the design phase.

1.2 Collaborative strategies on microEDUC platform

The main goal of the microEDUC platform is contribute to the development of a scholar culture of microelectronics, nanoelectronics and nanotechnology in Brazil. For this, microEDUC platform was developed in an integrated fashion to social media strategies to support the dissemination of knowledge to communities of teachers, students from technical schools level, and engineering schools.

The Microelectronics for 60 years accumulated knowledge of many areas of human knowledge and not just the chip manufacturing processes or integrated circuit design engineering. In the broadest sense, the Microelectronics Education, discusses knowledge of various areas of engineering: computer engineering, electronic systems engineering, telecommunications engineering, materials engineering, chemical process engineering, production engineering, etc.

The microEDUC platform was planned to support the issues involved in the Microelectronics Education, but indirectly, depending on the strategy employed in the future, may serve to attract or arouse the secondary school students, interest in engineering. The microEDUC platform was created in the style of virtual community to gather people interested in addressing a variety of issues on emerging technologies in the fields of microelectronics, nanoelectronics and nanotechnology. In this context the authors undertook efforts to model, develop, implement and test a web-collaborative mobile platform that could meet a wide spectrum of interest in Microelectronics Education.

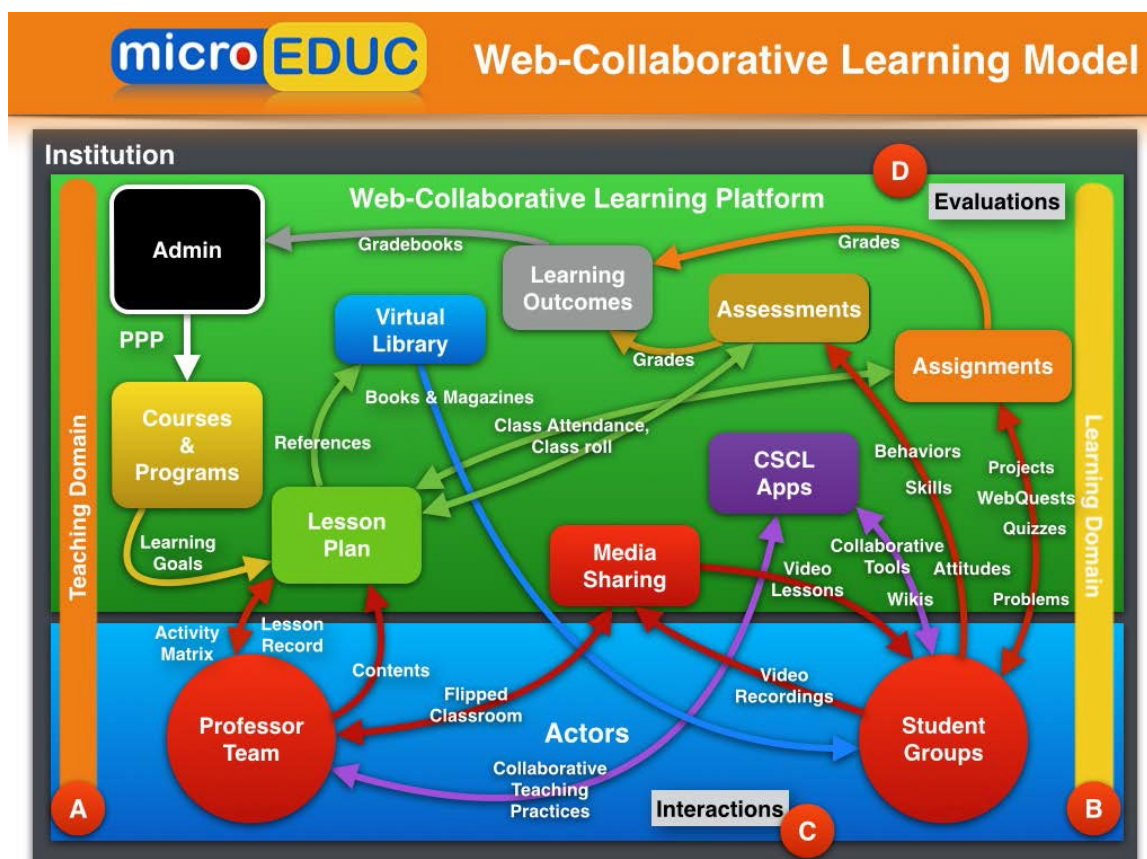


Figure 1: Web-Collaborative Learning Model used in microEDUC platform.

By Web Collaboration should be understood as a class of collaborative web-based tools and work strategies being researched and studied in the CSCW field. In education, the Web Collaboration is researched in the field of CSCL, Stahl at al (2006), and may involve the use of various techniques, methods and tools covering all aspects of collaborative work in educational activities.

Figure 1 shows the schematic model of web-collaborative learning model used and main elements on microEDUC platform. Collaborative interactions are considered in two domains: teaching domain (A) and learning domain (B). Considering the support of the administrative activities in educational institution, preparation of proposals for courses and programs, education planning, lesson plan, lesson record, class attendance, attendance sheet, class roll, strategies and practices of teaching and learning, educational activities, virtual library (books & magazines), video lessons and video recordings shared on video library, assignments (projects, webquests, quizzes, problems), reviews, assessments, learning outcomes, gradebooks, feedbacks, virtual environments for teaching-learning and mobile apps for CSCL.

The modeling of microEDUC platform involved several collaborative tools. STML and CM were used to define functionalities for microEDUC platform. For Web-based Collaboration (WbC) were considered Web Apps like Google Sites, Blog, Gmail in Google Apps for Education; Chat, Discussions, Meeting, Docs and Wiki in Zoho Apps. For Cloud-based Collaboration (CbC) the following technologies were used: Dropbox, Evernote, Mega Cloud, Box, CloudMe, BitCasa, SME with CloudOn, Documents and QuickOffice Pro Apps; Microsoft Office Web App in SkyDrive, and Google Docs in Google Drive. These apps have been tested in different devices like netbook, notebook, tablets and smart devices: (a) Lenovo Netbook with Microsoft Windows XP and Google Chromium OS; (b) LG R590 Notebook with Windows 8; (c) iPod Touch 4th generation (32GB) with Apple iOS 6; (d) iPad II (64GB/WiFi) with Apple iOS 7 (Figure 2); (e) Apple TV; and (f) LG SmartTV set model 32LW5700.



Figure 2: The microEDUC platform developed for mobile devices. < <http://www.microeduc.com> >.

In May 2013, the blog "Teachthought.com" published an article titled "5 Less-Known iPad Apps For The Flipped Classroom" briefly describing five mobile native apps for iPad, unknown from the general public for screencasting productions. They are: Explain Everything, ScreenChomp, Knowmia Teach, Doodlecast Pro and Doceri. From June 2013, all these mobile apps have been tested. In October 2013, the apps were officially recommended to 260 registered members on microEDUC blog: < blog.microeduc.com >. With only three years of operation, microEDUC blog reached the milestone of one million page views.

Hyde (2012), describes mobile applications like small software with specific features developed for mobile devices. There are two types of mobile applications: mobile native apps and mobile web apps. Native apps are written for each device type, need to be downloaded from a website or an app store and installed on your device. Web apps run inside web browsers and are written in HTML and CSS, JavaScript and Java Applets can download. How a web page is stored in web server. To operate, the mobile device needs to connect to the website.

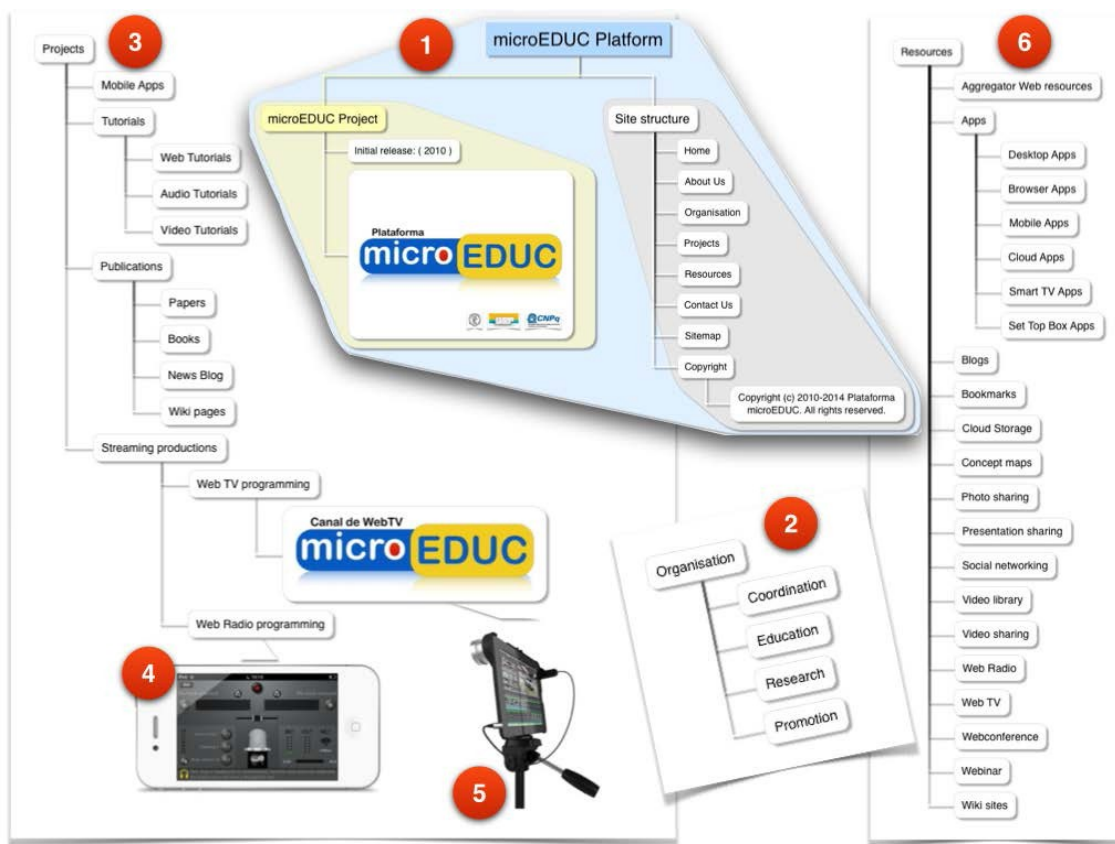


Figure 3: The internal organization of the structure of microEDUC platform.

The microEDUC platform modeling was initiated in 2009 and released for testing in 2010, through the package of services Google Apps for Education (Figure 3) and DNS name registered on Name.com (an excellent internet service

provider). The platform main page (Figure 3.1), was structured in the style of websites "Web 1.0", with the following pages: Home, About Us, Organization, Projects, Resources, Sitemap and Terms of Use, Privacy & Copyright notes. The organization of the platform (Figure 3.2), involves four areas: coordination, education, research and promotion. The projects developed and published in microEDUC platform (Figure 3.3), involve: Mobile Apps, Tutorials (web tutorials, audio tutorials and video tutorials), publications (papers, books, news blogs, wikis, OCW and MOOC), Production of webcasting for Web Radio (Figure 3.4) and Web TV (Figure 3.5), from mobile devices using mobile casting technology Apps (Spreker, Veetle, Livestream, UStream, Streamgo, YouTube Live and others) . The resources used in the platform (Figure 3.6), are based on integration with social media in collaborative style "Web 2.0" described by O'Reilly (2012), such as: Web media aggregators, several applications for Desktop Apps, Browser Apps, Mobile Apps, Cloud Apps, Smart TV Apps, Apps Set Top Box, Blogs, Bookmarks, Cloud Storage, Concept maps (CM), Photo sharing, Presentation sharing, Social network, Video library, Video sharing, Web Radio, Web TV, Webconference, Webinar, and Wikis. Figure 4 shows an illustration involving all of these features.



Figure 4: Resources and technologies for Web collaboration & Cloud Collaboration used on microEDUC platform.

2 Methodology

A simple methodology were developed considering the user centric view point for analyzing features of web or mobile applications named Apps Functionality Analysis (AFA), focused on the point of view of the users to understand the main functionalities of apps. The AFA methodology uses a language defined as Structured Text Markup Language (STML) which presents as markup text plan with hierarchic structuring, metadata and hypertext, used to organize the interfacing to management systems Personal Knowledge Bases (KPBm) and graphical visualization of Concept Maps (CM) based on mobile native apps.

Tests were made to capture audio and video with professors at the Polytechnic School of University of Sao Paulo, Brazil, for the study of techniques and formats suitable for video lectures in these technical areas. And, two environments were tested for production of video lectures: a) the normal classroom adapted as a TV studio, and b) another mobile studio assembled with a variety of arrangements of elements of scenery. Several popular models of digital cameras and camcorders like low cost flip-camcorders were tested, with qualities of mono and stereo audio (MP3, 128 Bit) and video format VGA SD (4:3 with 640 x 480 pixels) and high definition Full HD format (16:9 aspect ratio with 1920 x 1080 pixels). The contents and formats of audio and video media, tested and disseminated on

microEDUC platform were produced according to the traditional model dedicated to the production of radio and TV (pre-production, production and post-production), widely used in broadcasting terrestrial, satellite and cable.

The audio and video media were tested in Internet TV (IPTV), WebTV channels in experimental set up for the live broadcast using up stream via media encoder installed in movable WebTV studio environment, with subsequent posting on channel for video on-demand (VOD), with distribution of RSS Feeds of podcast program formats hosted in online video library. Some tests were performed using live broadcast of experimental productions of audio and video contents with HTML code embedded in public and private web pages, built in microEDUC domain. Several models have been proposed to web radio and WebTV programs with specialized contents for microEDUC, but only a few riders of short film series were produced and tested, supported on topics based on books and specialized sites on microelectronics.

Mobile apps were modeled, developed and tested using creative multi-platform mobile application online using Apps Builders like web-based software with technologies HTML5, CSS3, JavaScript and PHP, and also some iOS and Android native apps using software development kits (SDK): webinar; web conference; virtual classrooms; virtual collaborative spaces; virtual research laboratories; thematic online video libraries; virtual script workshops for web radio and WebTV screenplay productions; web collaborative dictionary; virtual publishers for books edited web collaboratively; and collaborative book editing.

3 Development

3.1 Video lessons on basic electronics course (PSI2306)

Professors at the Polytechnic School of the University of Sao Paulo (POLI) released in June 2013, the first video directed lessons to students enrolled in the electrical engineering course of basic electronics, discipline (PSI2306). This initiative included the participation of the following teachers: Dr. Wilhelmus Adrianus Maria Van Noiye (Figure 5.1 and 11.2), Dr. Armando Antonio Maria Laganá (Figure 5.2 and 11.3), Dr. João Antonio Martino (Figure 5.3 and 11.5) and Dr. Antonio Carlos Seabra (Figure 5.4 and 11.4). These professors teach in the Department of Electronic Systems Engineering at POLI, and are responsible for PSI2306.

In view of professors, students enrolled in PSI2306 now have more options to learn electronics: (a) they can attend lectures in person in the classroom, to assimilate key concepts taught in the scheduled days; (b) watch the video lectures anytime and anywhere, to review what was taught in the classroom in case of absence; (c) learn effectively reviewing lessons several times, at their own rhythm, to understand better all the concepts.

In the opinion of the students, the course PSI2306 is very rich in content and very hard too. It requires many daily hours of dedication to understand and fix all the concepts involved. The video lessons option can help them review the important points that were not well understood in the classroom.

Professor Dr. Antonio Carlos Seabra (Figure 5.4), produced the first video lessons for PSI2306 with

screencasting software (Camtasia Studio), capturing the screens of your notebook and recording their explanations in a video file output. In the PSI2306 video lessons, students can find all the information about the topics of the syllabus, as well as important tips on exercises, periodic assessments, resolution of didactic exercises, general explanations for individual activities or in workgroups, and lists of exercises recommended. The direction of the test footage was taken

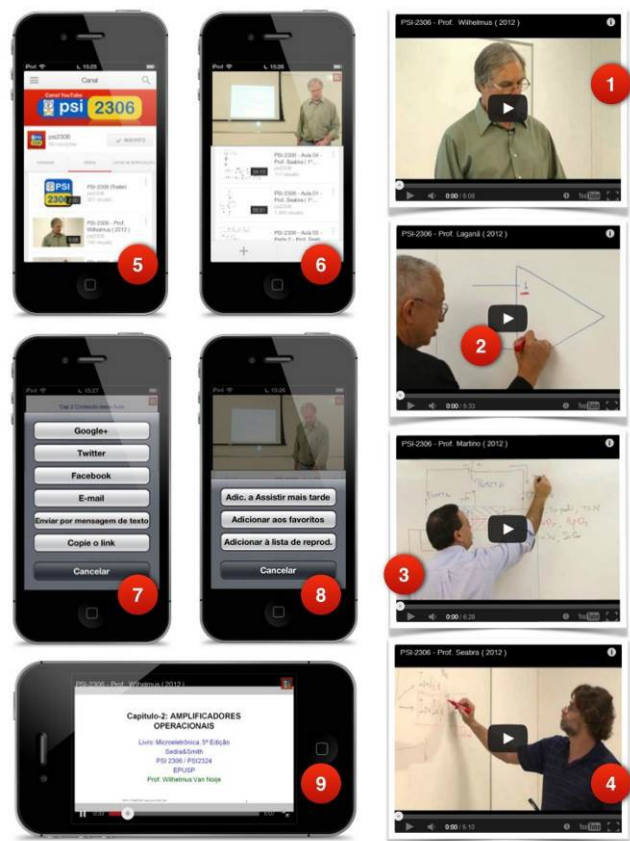


Figure 5: First test video lessons produced for PSI2306 discipline to mobile apps: < <http://psi2306.microeduc.com> >.

by Professor Dr. Luiz Fernando Santoro (Figure 11.6), Department of Journalism and Publishing of the School of Communication and Arts at USP (ECA), under the coordination of the authors.

3.2 Laboratory of Microelectronic Devices Fabrication (PSI2643)

This course, since 2010, has been offered annually to students of electrical engineering at the Polytechnic School of the University of São Paulo. The course was created by the initiative of professors in the Department of Electronic Systems Engineering, working in the areas research in manufacturing processes for microelectronic devices and microelectronics education.

The PSI2643 is recommended to students attending the 10th period of electronic engineering. Thus, the Polytechnic School of the University of São Paulo is managing to provide its students an experiential learning 60 hours, essentially practical character, students who attended in previous periods, the major disciplines of integrated circuit design course offered in degree in electronic systems engineering.

The PSI2643 was structured following the philosophy of Alison King (1993), with professors instead of being the "sage on the stage" participate in the activities of students as a "guide on the side", facilitating learning. Thus, PSI2643 offer to the students a basic general vision for the current Electric Engineer, giving the chance to participate of a project, manufacture and electric characterization of an integrated device. It is an only experience where just few under graduation students in the world have the chance to know, in practice, whole the complete cycle, involving each step in manufacturing of microelectronic devices.

In general, the lesson planning for PSI2643 covers the following topics:

1. Introduction to the course; history of microelectronics and nanoelectronics; devices in integrated circuits;
2. Basic concepts on the basic process steps in microelectronics. One complete integrated device process fabrication will be presented to be studied during the course (as for example: diode or capacitor or transistor or a small circuit);
3. Introduction to the simulator program (MiniMOS), that will be used to aim the project of the device;
4. Silicon wafer characterization and cleaning procedure;
5. Thermal oxidation/oxide deposition and measurements of the oxide thickness obtained;
6. Photolithograph and etch (definition of the component layout);
7. Doping step process: diffusion/implantation (formation of regions N and P).
8. Metallization step process (for devices interconnections);
9. Bounding Techniques;
10. Electric characterization of the manufactured device (Part 1);
11. Electric characterization of the manufactured device (Part 2);
12. Evolution of integrated circuits (seminar).

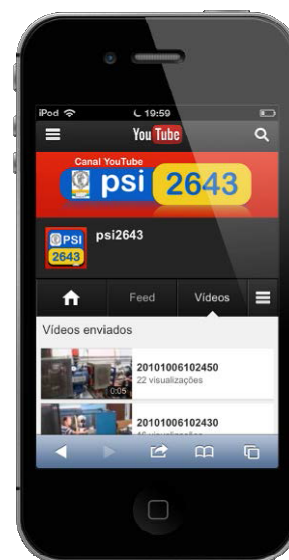


Figure 6: PSI2643 video collection created with App Builders and videos shared on YouTube: < <http://psi2643.microeduc.com> >.

In Figure 6, is showed the PSI2643 video collections on a mobile application created with App Builders and video playlists shared on YouTube, under Creative Commons licenses, open to create derived works for non commercial use.

In Figure 7.1, Professor Dr. Marcelo Carreño briefly explains the basics involved in the processes that will be realized in practical activities. Professor Dr. Marcelo Careño, divide students into groups who will participate in didactic activities simultaneously in two laboratories (Figure 7.2). Instructor guides students on safety measures and care in handling toxic gases used during the manufacturing processes (Figure 7.3). Instructor explains to students how to use the masks to protect against leaks of toxic gases into the laboratory (Figure 7.4). A manufacturing guide is distributed to students at the beginning of the course, containing the details of all procedures to be performed (Figure 7.5). Instructor explains the process of ellipsometry, demonstrates the equipment. Students complete their group activities (Figure 7.6). Instructor explains the process of profilometry, demonstrates the equipment. Subsequently, students complete their group activities (Figure 7.7). Instructor explaining to students the procedures and personal care that should be observed when handling chemicals in the chapel (Figure 7.8).

In Figure 8.1, instructor demonstrates to students the process of cleaning the silicon wafer. Instructor explains how works the thermal oxidations and impurity diffusions (Figure 8.2). Instructor explains how to insert the blade magazine into the silicon thermal oxidation furnace (Figure 8.3). Students look to the dangers and care in and out of the carrier

at high temperatures: 900 °C to 1100 °C (Figure 8.4). The charger of silicon wafers is introduced slowly in the oven at 1100 °C (Figure 8.5). Images masks designs of integrated circuits LSI manufactured in USP are used to demonstrate the process of lithography (Figure 8.6). Instructors explaining to students the photographic process used in the 70s to reduce the images of masks (Figure 8.7). Students check details of the images on the projector to reduce images (Figure 8.8).

In Figure 9.1, instructor of pictures showing the size of the chip on the surface of quartz mask with thin film of chromium. Silicon wafer preparation with photo sensitive emulsion during the lithography process (Figure 9.2). Instructor guides students how to align the masks on the silicon wafer to start the lithography process (Figure 9.3). Students are instructed on the hazards and precautions to be taken with the emission of ultraviolet light aligner (Figure 9.4). After each process performed, student is checking the process quality with optical microscope (Figure 9.5). Students check all images on silicon wafers to decide whether the process was well done, continue. Otherwise, the silicon wafer is reprocessed (Figure 9.6). After each step is completed the students met in the optical microscope if any error occurred (Figure 9.7). Instructor is demonstrating how to attach a piece of silicon wafer in the sample port to be used in plasma equipment for thin film deposition (Figure 9.8).



Figure 7: PSI2643 video collection.



Figure 8: PSI2643 video collection.

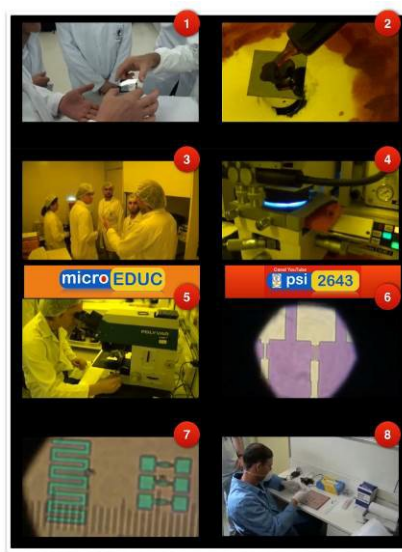


Figure 9: PSI2643 video collection.

The PSI2643 video collection is composed by about 500 short films that can be used for anybody to edit into video online editor, in YouTube account, just typing: PSI2643.

3.3 Web TV and Web Radio Experimental Studio

In this work we developed a mobile studio with 18 square meters to broadcast Web Radio and Web TV productions (Figure 10), used for capturing and recording of lessons and video tutorials (Figure 11), supported by three styles of Web TV Kits:

- 1) Equipment kits for audiovisual production (Figure 12), composed of low-cost equipment, used in audiovisual semiprofessional productions (digital cameras, camcorders, accessories, audio and video cables, audio and video mixers, character generators, audio and video recorders, audio and video editors, video capture cards, media players (HDD, CD-ROM and DVD), video cassette (VHS), Web Radio and WebTV transmitters, sound amplifiers, TV monitors, video projectors, computers, Wi-Fi communications and internet access, accessories, tools and components for maintenance);

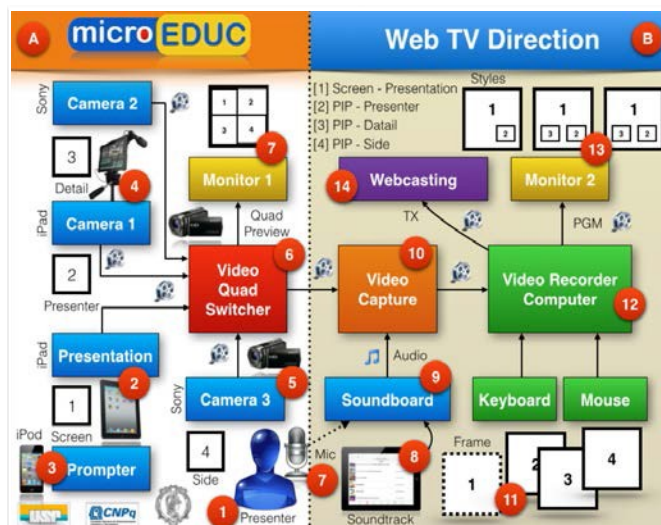


Figure 10: Scheme of audio & video productions oriented to Web TV:
< <http://tv.microeduc.com> >.

- 2) Kits for mobile studio, composed of structural elements used in the assembly of the semiprofessional studio as walls, ceilings, floors, thermal insulation, sound insulation, acoustical treatments, elements of scenery, traveling, electrical, lighting, accessories, hand tools and electrical tools, and
- 3) Apps kit, consisting of desktop software (PC and Mac), web apps, browser apps and mobile apps (native and web-based).



Figure 11: Mobile studio for capturing of video lessons and video tutorials: < <http://studio.microeduc.com> >.



Figure 12: Studio equipments organized in Web TV Kits: < <http://kits.microeduc.com> >.

4 Conclusions

Using AFA and STML to analyze the common features of web-based collaborative apps, gadgets, widgets and add-ons was possible, which were plugged-in Chrome browser for Desktop, Chromium OS, and mobile collaborative apps. In this case, simplifying our understanding, learning and developed didactic activities using available apps for smart devices like iPhone, iPod Touch, iPad and LG Smart TV.

Virtual web-based platforms, supporting collaborative editing (wiki pages or blog postings) can be very useful to motivate students and productive in the development of assignments or projects in cooperative and collaborative learning. Resources and technologies surveyed in this study shown to be potentially suitable to promote popular science of great impact and develop educational content in the areas of microEDUC whether the follows recommendations are adopted:

- 1) Resources for peer production;
- 2) Collaborative media technology;
- 3) Live broadcasting technologies for Web Radio and Web TV;
- 4) Video on-demand technology (VOD);
- 5) Full mobile device compatible technologies.

We believe that students in engineering courses can be better prepared for the real world with the help of new tools and active learning strategies associated with different approaches to collaborative learning. We note that, in the past two years, cloud collaboration has been used extensively in business and is turning into a great ally in education. New methods and strategies involving collective learning still need to be investigated to better understand the full potential of mobile collaboration with cloud collaboration technologies.

Taking into considering all these aspects presented in this paper about Web Collaboration in Microelectronics Education, our research on collaborative learning are just beginning. And our first results are being published in ALE2014 and microEDUC platform.

Acknowledgements

We thank CNPq for the financial support for this project. And also to Professor Dr. João Antonio Martino, head of Department of Electronic Systems Engineering from the Polytechnic School of the University of São Paulo (PSI/USP): Authorized the experimental filming undertaken in 2010 during the lessons of PSI2643, which featured the special participation of Professor Dr. Marcelo Nelson Páez Carreño (LME/USP); By testing video lessons about basic electronics disciplines of undergraduate Electrical Engineering based in the Book of Sedras & Smith (PSI2223, PSI2306 and PSI2324), which included the participation of teachers Dr. Armando Antonio Maria Laganá and Dr. Antonio Carlos Seabra.

We would like to thank the students who participated in the first class of the course Laboratory Microelectronics Manufacturing Devices (PSI2643), enrolled in the 2nd half of 2010. Special acknowledgments to coach Ricardo Rangel and technical team of the Microelectronics Laboratory (LME/EPUSP) and the Integrated Systems Laboratory (LSI/EPUSP), the received technical guidance and monitoring of students during all steps of the process that allowed students build your own nMOS transistors.

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Enerbio – Energy Transformation

Clara Maria Furtado⁺, Griseldes Fredel Boos⁺⁺, Paulo Roberto Brandt⁺⁺⁺, Simone Leal Schwertl⁺⁺⁺⁺, António André Chivanga⁺⁺⁺⁺⁺, Bruna Konkewicz⁺⁺⁺

⁺Assessoria Pedagógica, Universidade Regional de Blumenau, Blumenau, SC, Brasil

⁺⁺Departamento de Engenharia Química, Universidade Regional de Blumenau, Blumenau, SC, Brasil

⁺⁺⁺Departamento de Engenharia Elétrica e de Telecomunicações, Universidade Regional de Blumenau, Blumenau, SC, Brasil

⁺⁺⁺⁺Departamento de Matemática, Universidade Regional de Blumenau, Blumenau, SC, Brasil

⁺⁺⁺⁺⁺Instituto Superior Politecnico de Tecnologias e Ciencias, Departamento de Engenharia e Tecnologia, Luanda, República de Angola

Email: claramaria@terra.com.br, boos@furb.br, prbrandt.furb@gmail.com, simone.leal.schwertl@terra.com.br, chivanga@gmail.com, bkonkewicz@hotmail.com

Abstract

Engineering plays a key role in socioeconomic development in any perspective that we can analyze. The goal of the project ENERBIO - Energy Transformation is develop the interaction between the University and the high school students and teachers, with the implementation of Science Clubs for stimulate the realization of experimental activities that contribute to the development of a contextualized teaching of basic sciences. With the actions of the Science Club the schools were able to engage students of the two school levels in the production of biodiesel and its transformation into electrical energy. The dynamics of the project requires that different professors from different areas come closer in a dialogue that focuses on the relationship with the education. While there were moments in which each project member was concerned with different disciplines, possibilities for interaction and implementation of methods and reality understandings were opened among the whole team.

Keywords – high school-university integration, engineering, science clubs, science education

1 Introduction

The project Enerbio – Energy Transformation goal to promote interaction between the University and students of the participating high schools. The project aims to implement a science club in 4 schools and their interaction with the Center of Science and Technology of the University, showing for high school students in practice what they are learning in theory, besides increasing the interest for the in the field of exact and natural, also stimulate the curiosity for research in the areas of Oil, Gas and Biofuels and disseminate the technical, economic and social role of engineering in the production of environmentally sustainable goods and services, thereby contributing to the improving the teaching of Exact and Natural Sciences in high school.

The actions developed by the project triggered the interactions between different professionals and areas of knowledge around the processes biofuel production and its use in the energy transformation. In addition to the proceedings, the actions took as an intention the questioning that wraps the conception of interdisciplinaridade, either in the basic education and in higher education.

In this form, the challenge consisted in maintaining the dialog across differences on common objectives, process which has promoted actions that, in addition to the expected results, the reflection of professionals through continuing education which is characterized by moments formally planned or constant discussions among the participants of the research team. This article intends to add to the conception of the project, his characteristics, methodology, organization, as well as the actions that were developed along his execution.

2 Enerbio Project: Energy Transformation

The engineering, like producer of knowledge and area of professional formation, plays a key role in the socio-economic development, in any perspective that can be analyzed. The extraordinary technological advancement experienced by mankind in the last century is closely related to production in engineering because it is his function create structures, devices, processes, products and systems demanded by the society. On the other side, we must also consider the negative effects produced by this scientific development, emphasized by Valério and Bazzo (2006),

demanding a new look in this relationship science-technology-society and pointing again to engineering as necessary to produce solutions to the problems created by their own development.

It is understood that the training of engineers is a strategic resource for the nation and is accentuated the role of scientists and engineers as indispensable engines to achieve an economic and environmentally sustainable and socially just development. Despite its importance, notes a lack of interest among young people to pursue careers in this field in Brazil. This escape can be caused by many factors, but certainly one of which is the fear for the study of "harder" disciplines such as physics, chemistry and mathematics, can take as a cause the abstract teaching and little contextualized diagnosed in the Brazilian basic education.

A contextualized teaching and the effort of interdisciplinary actions are included in the National Curriculum Parameters of Basic Education - PCNs. These are guidelines that point to the need for curricula "engage, of the combined form, the development of practical knowledges, contextualized, to meet the needs of contemporary life, and the development of broader and more abstract knowledge, reflecting a culture general and a worldview" (MEC, 2000).

As for the teaching of science, one of the actions of the Department of Basic Education MEC is the implementation of a Plan for Science Education which aims to incorporate the practice and scientific reflection on the academic and social lives of students by encouraging the development of proposals and incorporating practical approaches and problem-solving. Such measures, coupled with a vision of transformative education, prepares young people to follow the career in technological professions such as engineering education. Due to its characteristics, training in engineering requires solid knowledge in basic sciences, competence that does not fall only to the University. However, it is for her to think of solutions that can contribute to basic education be strengthened and provide young people with an education that enables them to follow academic career in any area without the shortcomings perceived today.

The ENERBIO Project - Energy Transformation focuses on the interaction between the University and schools in MS, with the involvement of students and teachers of basic and professional core courses in Chemical Engineering, Electrical Engineering, Telecommunication Engineering and Forest Engineering. The project also articulates with four (4) graduate programs of the Regional University of Blumenau and students and teachers from four (4) High Schools of the State Education Network / SC (15th gered). Mediation with the state's public schools is done by 15th GERED and the project has financial support from FINEP - Studies and Projects (Public Call MCT / FINEP / FNDCT - PROMOTE - Engineering in High School 05/2006).

The project was structured from the formation of Sciences Clubs in the High Schools that interact with the Center for Science and Technology, under the coordination of the University. In this Nucleus, studies and works are developed with the participation of students and teachers of the two levels of education, for the implementation of experimental procedures biofuel production, from grease and its consequent transformation into electricity with sufficient quality and quantity to meet specific demands identified by the Science Clubs.

The project ENERBIO has been making possible the diffusion scientific-technician and of interaction with high school with the participation of the Regional University of Blumenau, from micro-plant of production of biodiesel using like raw material oil of fried food and with the installation in each school of systems of generation of electric energy using the biodiesel produced like fuel.

The production of biodiesel originating from oily residues, and his conversion in electric energy makes possible the diffusion of the scientific / technological knowledge together the school community of high school (EM) with sights to promote the technical, economical and social enlargement of the courses of the engineerings regarding the production of goods and services environmentally sustainable. The Project has been looking to motivate the spirit inventive / investigative of the students of the high school (EM) in the identification of solutions for demands of energy with execution of interdisciplinary activities developed in groups of work formed by students and teachers of the schools of secondary education articulated with students and professors of the engineerings and of the basic sciences.

In general terms, the project ENERBIO – Energy of Transformation looked for:

- develop strategies of involvement of students of high school, orientated by teachers, in activities of management and maintenance of the unity of generation of electric energy;
- wake the interest for the search of solutions for punctual demands of the school community in terms of energy, stimulating the inventive spirit;
- promote activities that contribute to the development of the environmental responsibility of the school community, highlighting the students, teachers, leaders, parents and other connected agents;
- promote interdisciplinary activities through the works developed by the teams (nucleuses) in management of the unities of fuel production and energy.

The early moments of the execution of the project pointed to the necessity of organizing a structure of management that could, in front the complexity and amplitude of the works, enabling his appropriate execution. In this sense, it constitutes a management team consisting of: a) General Management, b) Administrative and Financial Management, c) Pedagogic Management and of Formation. Such a strategy allowed the distribution of responsibilities and the articulation with the too integrant ones of the team, as well as with internal and extern organs.

2.1 Design of the methodological design Enerbio

The overall design of the Project ENERBIO presupposed that the process of teaching and learning at any level, should produce meanings, which can be achieved with strategies that are developed from the observation of a concrete reality, experiencing a moment of theoretical and then a return to reality for this intervention, either to make it or understand it. Involvement in practical activities, either through experiments or structured development projects that seek some kind of solution to the real problem may be strategies that enable this type of reflection-action.

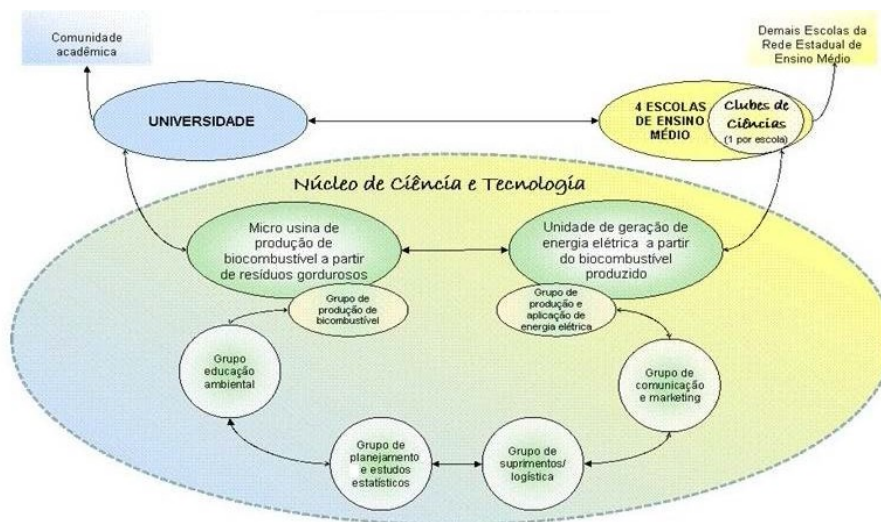


Figure 1 - Structure of the Working Groups
Source: Enerbio 2010

Based on this principle, the overall methodology that supports the proposed project is organized ENERBIO from ten distinct steps, developed by the Working Groups that are articulated with each other, as shown in Figure 1. Each group is responsible for a project area and address along with the high school students the importance of each topic.

- Group of Environmental Education - Educam: promoting reflection on the environmental impacts arising from the use of fuels, energy from non-renewable and alternative sources (renewable), the implications for the use of waste and its transformation into valuable products household, and other aspects of environmental relevance arising from lived experience, awakening critical and social responsibility;
- Group of Supplies and Logistics - Supri: supply the unit with fuel production feedstock required (cooking oil and other types of fat) proceeding to collect this in school community. Moreover, this study group should supply the unit of power generation with the biofuel produced, manage the other aspects necessary for the operation of the production units of energy. In this group, all students should develop skills in teamwork, gain knowledge in management of processes and services, taking the opportunity to apply knowledge from several areas in the implementation of the proposed activities;
- Group Planning and Statistical Papers - Planest: assist the Supri in the methodologies for maintenance of production units, develop statistical studies related to the collection of raw materials, the production of biofuel and the energy savings due to the use of electricity generated from biofuel and other quantifiable aspects of the activities performed at the Center for Science and Technology. In this activity students should significantly assist in the use of mathematical and computational tools, and develop skills foresight of performance, key elements in engineering education;

- d) Group of Production of Biofuels – ProBio: assistant in the operation and maintenance of the unity of production of the biofuel from oily residues (oil of fried food and other types of oily residues), and to implement studies around this process to identify the bases of the sciences applied in technological development;
- e) Group of Production and Application of Energy - Aplien: assist in the activities of operation and maintenance of the movable unities of generation of electric energy using the biofuel produced in the ProBio and to identify, in the school, the best use of the energy produced . Besides, it must organize activities that wrap the school community to identify other forms of application of the produced biofuel or of the energy produced . The activity, also permit to develop skills for identification and solution of problems, requisites that also compose the profile of the engineer; as well as nurture the application of diverse knowledge studied in high school;
- f) Group of Communication and Marketing – Comark: disseminate to the school community , both the anchor schools as other high schools of Public School , experience and learning gained through implementation of this project .

These groups take two main activities as the focus:

- a) the involvement of the students of high school in practicals class developed in two different contexts: in his school, under the responsibility of teachers of the basic sciences, and in the university, with practical classrooms driven by professors and scholarship holders of the courses of engineering;
- b) the participation of these students in a project aiming for production of energy through biofuel to feed a necessity or problem of his school, which sets herself up as the stage 8 of the project.

In the 4th stage of the project 8 (eight) mini-courses of formation was developed, with 8 hours-classrooms to enable teachers with potentiality to coordinate the Science Clubs. The mini-courses were offered for the teachers, scholarship holders of the secondary and superior education, being participants or extern community interested in the implementation of Science Clubs in the schools.

The qualification of the project participants will take place through the following courses:

Science Club and the scientific and technical education : theoretical and methodological assumptions - empower teachers with the capability to coordinate Science Clubs to be implemented in four (4) high schools involved in the project .

- Projects of scientific initiation in school : objectives , organization and implementation - Objectives of science education in high school , with contributions from different areas of knowledge for scientific and technical education . The steps of a research project , scientific skills and attitudes , registration and final synthesis (report) .
- Reading and writing as a tool for scientific education in the classroom - Reading and writing lessons in Natural and Exact Sciences , as well as explored the functions of reading and registers in projects of scientific research and scientific text in the classroom .
- Oil - Basic knowledge of geology, exploration, petrochemicals and fuels industry and generating inputs . The content should be related to the theme of the environment , geopolitics and economics .
- Oil in Brazil - History of oil in Brazil , the company Petrobras . Furthermore , we discuss the issues of deepwater exploration , the discovery of pre-salt and the Brazilian petrochemical industry . The relationship to be established with the themes in articulation such as environment , economy and social development .
- Biofuels - Historical aspects in relation to production of biofuel from ethanol , second generation ethanol , vegetable oils . Biodiesel, Oils ' biolubricants ' . The discussion environment will impact on the relationship with food production .
- Quality Control Fuel - The adulteration of fuel, the impact on the economy , the quality control of fuels , economic development, and the greenhouse problem .
- Energy and environment - explores the energy and environmental technology , environmental management and energy balance , conventional and alternative sources of energy. Also addresses the environment and selective collection of waste , the energy potential of domestic and industrial waste and household waste as an energy source .

Inside the project we attach importance to articulation between the departments. Different from the university that remains broken up, in spite of the structure of Centre, in other words, the practices of the courses are limited to the curriculum. The dynamic of a project as the Enerbio obliges the different teachers of different areas (basic and vocational) they approach and establish a dialog centered in the focus of the articulation and taking still the work with the high school. Though in the context of the project each one deals with different fields / disciplines, if it establishes a rich dialog and there open means of interaction and transposition of methods and of understanding of the reality between all.

How teaches Japiassú (1976) “ the interdisciplinaridade is characterized for the intensity of the exchanges between the specialists and for the degree of real integration of the disciplines, in the interior of a specific project ”. It is this

experience what the project ENERBIO has proportionate. To apprehend this experience, to understand it in its amplitude and to spread it out for other contexts has when if another challenge was shown. We establish an integration of the departments and of the co-ordinations of course, contributing so, not only for high school, but for the teaching practice itself in the university.

3 Pedagogical Actions brought from Enerbio Project

3.1 Environmental Education

In the present the information assumes a predominant paper in all the ways like the multimedia and Internet. The education for the citizenship looks to motivate and touch citizens to turn several forms of participation into the defense of the quality of life. In this sense it is needed to detach the environmental education like the form of transform with co-responsibility of the individuals into the promotion of the new type of development – the sustainable development. In this perspective, the environmental education is necessary to modify the growing picture of degradation socio-environmental, but tools of mediation are still demanded more between cultures, differentiated behaviours and interests of social groups for the construction and proposition of the wanted transformations.

In this preamble, the students of high school wrapped in the project ENERBIO pass them over a rigorous formation, through mini-courses on the environmental education, potentializing them to discuss subjects connected with the biodegradation and several impacts resulting from the unsuitable arrangement of the oily residues on the environment. With this qualification, these, in the articulated form with the teachers of the schools of the Secondary education and of the University, carry out workshops and seminars on the environmental education in the schools for potentialize environmental knowledge connected with the formative subject during the minicourses. This work also is spread in too many schools of high school in the area of range of each school like strategy to enlarge the knowledges on the environmental education.

The tireless search of the humanity for energetic resources is incessant at present. They all look in the nature, raw materials for the production of his industrialized products generally in function of sale and of the profit. In counterentry, there are resources discarded by the human being that might be re-used if they were obtained simultaneously profit and benefit to the environment, like discards it of the residual oil of kitchen or oil of fried food.

This residual oil discarded incorrectly can produce countless problems if discarded in the ground, since the waterproofing of the same thing causes, obstructing the infiltration of the water, destroying so, the local vegetation and collaborating also for the increase of rate of flood (PARADISE, 2008). In rivers and seas, it causes death of most of the aquatic life, since it obstructs the incidence of light and consequently of oxygen, altering so, the ecosystem (VERTICAL WORLD, 2008). Without mentioning the degradation of the box of fat of the residence that removes the oil for storm drains or wash basins, causing blockage and consequently increasing the costs of cleaning and maintenance.

The collection of residues of oil of fried food is supported by prior works of environmental education and for the thorough definition of the most appropriate proceedings that guarantee the knowledge of the time limit of use of the oil in the processes of fried food, cooling of the oil and consequent insertion in bottles PET's previously selected. To define the routines of collection, the group of investigators of the project ENERBIO developed, in the distance of the activities of the project, minicourses administered for all the students of the secondary education with activities in the clubs of science. The referenced course makes possible reflections on the environmental impact resulting from the unjust arrangement of the oily residues, the energetic importance and the potential of production of biofuels.

In the development of the activities established by the group, the project ENERBIO it listed proceedings of collection and storage of the oil cooks in order that participant was handed to the coordinators of each school with the intention of they to spread the project to the students of the school centre. With this short presentation of correct methods of collection and storage, a better organization of the retirement was possible and consequently a better profit in the executed activities.

The proceedings when were detailed folders had like references principally of the SABESP with the program entitled "PROL" - SP, the program of retirement "Echo oil" - SP and of the program "of Oil in the Future" – SC.

- a) the oil of fried food to be collected must be stored in bottles PET or in the container itself of the pure oil;
- b) the bottle for storage cannot be washed by soap or any other chemical product, only by water to avoid the contamination of the oil;

- c) before the oil was stored it can be filtered by a cloth or a sieve;
- d) after the oil is poured in the bottle, same it must be quite forbidden to avoid leaks;
- e) the bottle with the oil must be maintained at dry, quite ventilated places, out of the children's reach, far from the ground and avoiding elevated temperatures;
- f) the bottle sent for the school must be carefully guarded and put in the appropriate flagons and properly identified;
- g) to manipulate the oil they are due to use gloves;
- h) the transfer of the oil of the bottles for the flagon must be done by funnel;
- i) the bottles must be returned to the students, to be re-used in new collections;
- j) when the level of oil in the flagons to reach 4/5 of his capacity (near to the edge), the container must be prohibited and stored in appropriate place (at dry, quite ventilated places, out of the children's reach, far from the ground and elevated temperatures), waiting for the date of collection.

In the course of the project, the transport was carried out by the use of a specialized and equipped vehicle of the FURB. The vehicle generally used for transport of biofuel is fitted in the requisites of the standard prearranged by the ABNT, being used for the appropriate transport of the biofuel I eat also of the oil of fried food. The use of the vehicle was used fortnightly, passed the time and the quantity of oil gathered by the schools in the established period.

The transport logistics of the flagons was carried out in the next way: firstly, a flagon was transported for each school and when a date was designated it specifies for his retirement. The day of collection was mainly established by the school. In the day designated for the collection of the oil by the FURB, besides gathering the flagon of the schools, the responsible vehicle was still taking another flagon to the near collection, with intention of the collection did not stagnate. Near the vehicle and the flagons of oil of kitchen, an envelope was containing the FISPQ (Token of information of security of chemical products) of the residual oil and a term of condition for the donation of this oil for the school bound for the FURB.

The available material for the investigators constitutes in the material of reference for diffusion of the aspects pointed above in the schools potentializing the environmental responsibility of each student and teacher of the schools. With the actions, there are carried out campaigns of collection of oily residues in all the schools wrapped in the project, with incisive directions on the basic proceedings of collection, taking the delivery of bottles PET's as a starting point for the students of high school.

On the other side, there was done the structuring of a physical space where they are put flagons, necessary for receiving of the residues collected by the students, up to the volume limit of 50 liters. With the reach of the specified volume, the residue is transported for the university for processing. In the University, where the micro-factory is installed for the production of biodiesel, in accordance with the proceedings contained in this article there are executed conversion experiments of oil of fried food. With the arrival of the oily residue in the university, the students of high school, with students help of the degree courses, of the master's degree and of the teachers of the university carry out conversion experiments of the residue in biodiesel, in accordance with the proceedings previously definite and described in this work.

When the work of production was ended of biodiesel, this biofuel is inserted in flagons and transported for the school where there is installed a generator operated with biodiesel. The produced biodiesel is inserted in the system creator and the produced energy is used to attend specific demands of the Clubs of Science or other spaces previously defined by the direction of the school, of form articulated with the clubs of science.

The gaseous emissions originating from the production of the electric energy, through the system creator, are monitored through measures of the fractions of carbon dioxide, carbon monoxide, dioxide of sulphur, dioxide of nitrogen, temperature and pressure and when fossils were compared with the emissions originating from the combustion of the fuels. Besides more, the quality of the produced energy is monitored by the team of students and teachers of the Department of Electric Engineering and Telecommunications of the Regional University of Blumenau with constant attendance of the students and teachers of the schools of secondary education.

3.2 Biodiesel Production

For the production of biodiesel, the students of the schools wrapped in the project ENERBIO, carry out works of environmental education and collection of residues that are transported for the university to be converted in biodiesel, for chemical reaction of transesterification with homogeneous catalysts. The residues are unloaded, filtered, weighed and inserted in the tank of food of the oil of the micro-factory. With the mass of the known

residue, one proceeds to the stoichiometric balance in order to determine the necessary masses of the alcohol and of the catalyst for the reaction.

Next, the mass of the alcohol is inserted in the tank of reagents of the micro-factory and when the bomb was operated for its transport for the reactor, for subsequent heating. When the temperature of the reaction was reached, the mass of catalyst previously weighed is dissolved in the alcohol and inserted in the reactor, when zero of the reaction is constituted in the time. The parameters of the chemical reaction, like temperature, time, degree of agitation and the operational performance, are accompanied in the distance of the reaction. When the reaction was ended, the alcohol is recovered in excess, when the phases were separated and when the biodiesel purified.

The execution of the experiments of production of biodiesel makes possible the understanding of the conversion beginnings, commonly when they were implemented along the Engineers' formation. Besides more, the wrapped students look to understand on the energetic potential of the biomass, production of biofuels in bigger scales, the chemical beginnings involved in the processes and principles of engineering as crucial for technological development. Potentialize also reflections on the environment and his sustainability besides the demands of electric energy and production of residues in the operation of the micro-plant of production of biodiesel.

All the stages of production of biodiesel described in this work are executed by students of high school, helped by students and teachers of the university. During the execution of the tests hypotheses are lifted, when reflections were done and questions to sharpen the critical census of the students of high school in the science clubs with a view to future entry for this training in engineering.

3.3 Production and Application of Energy

The group Aplien takes the schools as an auxiliary objective in the activities of operation and maintenance of the movable unities of generation of electric energy using the biofuel produced in another project in the FURB, in the ProBio and in the identification of the best place for use of the electric produced energy. Due to generation of energy and the biodiesel to be made a list, connections of activities are established for the clubs of sciences like: you investigate on the residues that are produced in the manufacture of the biodiesel, like the use of the glycerol (residue) for the production of liquid toilet soap or bar and the purposes of use and functioning of a creator.

The activities allow that these students of the sciences clubs identify the forms of inquiries that can be used and practices wrapping theoretical knowledges. Besides, they develop the forms of helping the community and even at home, besides developing the skill of identification and resolution of problems. Through the clubs of sciences it has the opportunity for going over again for the school community, it presenting when it resulted from his inquiries and practical experiences, with the realization of scientific displays in the schools.

The acquired creator (Figure 2), was produced by the enterprise White, with which a partnership was established, since the common creator, produced for same, it is done to work from the supply of petrol. With small alterations done by the enterprise, we maintain the contact to update as the functioning of the creator goes with the biodiesel. We maintain contact with the enterprise, since we can analyse the profit of this creator, and the one who can bring an improvement of this creator in the future come to supply the market.

The creator is responsible because of transforming any type of energy (mechanics, chemistry, etc.) in electricity and in case of the project chemical creators were acquired. The use of this, generally take place during periods where they do not present energy and there is no another way of be producing. It has the purpose to help to give maintenance of the activities developed while passing of the day. The second use is to save energy come from the net, consequently obtaining a reduction in the count of light. The creator can be used every day for a period of 3 consecutive hours or in two periods of 2 hours each.



Figure 2 - Power Generator

For the development of the process of transformation of energy, some proceedings were necessary, thinking that the creator was acquired in the market and passed by a series of tests and tests so that the team recognized the technical proceedings for his use. This process disposed of the involvement of the team of investigators of the university and, at a first moment it caused problems that were obstructing the performance of the creator.

In the first time the test caused the blockage of the filter, since the produced biodiesel was in pasty state (gel) after 48 hours that demanded the cleaning of the filter and that on account of the use of ethanol to solve the problem collected to a creator a tank supplied of diesel. After the departure the valve of the diesel was closed, and it was leaving the creator working with his tank itself I contend biodiesel. Near when was disconnected the valve of the tank of the creator it was disconnected and that of the diesel opened again, for which cleaning of the tracks of the biodiesel contained in the creator, avoiding so a possible blockage of the filter. Finally, with more some studies done to discard the use of the auxiliary tank, it was possible to begin new production of biodiesel, exchanging the etanol for methanol and improving the rate of acidity of the oil of fried food, avoiding the blockage of the creator and putting in order for his full functioning.

Each school defines the purpose for the creator, taking into account his capacity and his assistant's principal objective at moment of emergence (lack of energy) or to cooperate in the economy of energy. The next demands were lifted for the use of the creator in each school:

- a) EEB Hercílio Deeke – lamps of the secondary school only in the nocturnal period;
- b) EEB Governador Celso Ramos – energy in the room of computers of the school;
- c) EEB Valério Gomes – energy in the room of computers of the school;
- d) ETEVI - to operate the lights of emergence of the Central Library in the cases of lack of light.

The schools maintain the functioning of the creator periodically, so that there is the regularity of operation and generation of the energy and consumption of the biodiesel and renovation of this, I eat also the correct maintenance of the equipment itself what there is no interruption of the energy.

3.4 Creating a Blog

This virtual environment used for education ends, presents itself a facilitator of the collective construction of knowledge, as soon as it makes possible what all the wrapped ones announce, writing posts and comments, preparing questions, publishing works in the form of texts, videos, reports, doing links with platforms of inquiry, finally exploring the whole scale of resources available in the cyberspace. We understand that the blog can be a tool of enlargement of the discussions initiated into present spaces and of participation more effective of the students in the process of teaching and apprenticeship.

The blog: Science Clubs – FURB/FINEP was raised through the free service Blogger. From a perspective of work in group the blog presents six pages where it is presented a little of the Club of Sciences carried out in each one of four schools participants of the Project ENERBIO. In the page "The Project ENERBIO" there shows up a synthesis of the Project that has like purpose establishes an articulation between schools of engineering and schools of middle level of teaching. Through the posts of the initial page a space intends to establish to negotiate in the form articulated the subject biofuel, as well as to establish a dynamic link of communication between the Science Club and the University.

The resources of a page available in the blog make possible that each Science Club organizes the content and promotes discussions and to reflections about the activities carried out in the context of the Project ENERBIO. The function of each school in the blog is centered in feeding the topic with materials of study and favoring a general discussion between the Clubs, besides using this tool to know the works carried out in other Clubs of Sciences, as well as to exchange ideas, in order to build new projects and activities in his respective Clubs.

There stimulate the participation of the students clubbers so that they feel a desire to suggest new topics for besides what they were treated at the moment of preparation of the blog. The posts of the initial page of the blog help in this practice and can be used to send too many pages of the blog and to bring contributions that complement the discussions on the central subject of the Project ENERBIO, the biofuels. The interactivity offered by the Internet does so that the posts of this space can be connected by other interesting subjects made a list to the principal subject - the biofuels - supplying so more informations than can produce new activities in the Clubs.

The blog is closed for the extern public, all the students and integrant teachers of the project ENERBIO participate like administrators of the blog and as such it has access to all the resources of production available in this environment. We understand that in this way, the authorship and the driving of the blog can be practical in the collective form and necessarily corroborating the apprenticeship in collaboration. Equally the blog was prepared by the intention of stimulating the practice of the inquiry in the continued formation of the teachers, as it points out

that Galiani (2003) the subject that uses the inquiry like process of formation develops the capacity of investigating, the criticidade and the autonomy.

In expectation of easing possible resistances for part of these students they participated actively of the process of production and idealization of the blog. Baltazar and Germano (2006, p.) while presenting when they resulted from an inquiry carried out with university young persons on the use of blogs they punctuate 8 and 10: " ... the principal motive in order that they do not participate more actively in blogs of disciplines is the lack of motivation. Many students point to the fact of existing an obligatoriness of participation in ourselves a factor of lack of interest". In case of the Clubs of Sciences, the problems pointed by Baltazar and Germano (2006) are being eased, first because the structure of the Project ENERBIO corroborates insertion of links of communication between schools and University, and second because the resource use of the spaces available in the WEB 2.0 they surface like challenges that were outlined in this new time in which the technology changes the form of communication, which consequently interferes in the way of teaching and of learning.

3.5 Educational Formation

It is a conviction of the group of the project ENERBIO that an effort of contextualization must favor an interdisciplinary approach of the contents of the secondary education, however the focus of the proposal, since it has assistance to make this one new pedagogic through moments of formation promoted by teachers of the courses of engineering and by the pedagogic advisory body of the project.

In the diagnosis carried out near the schools of secondary education, in the beginning of the project, it was possible to realize that the schools that already have a Club of Sciences, that develop studies and practical classrooms from components of the curriculum, coherently with the expectations General office of Basic Education of the MEC of incorporation of practical approaches and problematizadora in this level of teaching.

Meantime, the teaching formation what the project provides cannot be reduced at those formal moments of conversations or courses, but it already demonstrates to have impacts in the secondary education, as well as in the courses of engineering, through articulation of contents, of contextualization of the teaching, of adaptation of language and interdisciplinarity. The complexity of the technology can be realized in the discussions that wrap this theme, specially in the contexts of the basic and technological education. There happens, in these fields, the diversity of visions, conceptions and insights around the concept, when there is analysed the polysemy of the resultant term of positions of the subjects, very often loaded of meanings influenced by the areas of formation, cultural and / or professional, giving emphasis in the technical and scientific dimensions to the detriment of human and social (IT FILES SON, 2005).

On the other side, the pedagogic complexity of the project gives rise of the articulation between to several spaces of the educative practice been connected of the processes of assimilation of knowing and ways of action, having in sight the necessity of orientating the educational and pedagogic work what it includes:

- a) investigation of educative practices;
- b) theory and practice of the teaching and apprenticeship;
- c) projection;
- d) definition of programs of formation continued for teachers.

It will be important to point out that the relation dichotomic between the dimensions technological pedagogic, defended by the technicist ideal, must be surpassed by the understanding that "... the new resources and technological ways, in the context of the practices pedagogic-educational, are connected, also, with processes of mobilization of subjectivities" (OLIVEIRA, 2001, p.103). These observations make increasing the expectation of positive reflexes, specially in the superior teaching, still that in range and intensity on this side of wanted and necessary, but they already represent an advancement in the process of teaching apprenticeship since the integrants of the team start to have better understanding of the dimension pedagogic-educationally in the formation of the teacher of engineering.

4 Conclusion

The experience that has been gained in the development of project ENERBIO even before obtaining the final results and even be an extension of the Connect project has among its members integrants the conviction of which incorporating scientific practice and reflection on life educational and social development of students, it helps to improve the preparation of young people in high school, to follow the technological careers such as engineering.

The high school cannot lose sight of this function and, without being vocational, should create opportunities for students the competences and skills for a conscious and critical positioning regarding the world that encloses it. So

contributing to produce meanings, connecting knowledges and favoring an apprenticeship in an interdisciplinary perspective, it is considered that the difficulties of understanding of the natural (basic) sciences can be minimized.

Aligned to his original objectives the project have been providing opportunities teaching practices to what they give dynamism and ressignificam the teaching of the basic sciences and promote the diffusion of the engineering. Still in the perspective of his objectives, an aspect what they come if standing out positively it is of what one makes a list to the dialogs produced between the teachers of the secondary education with those of the superior teaching, and more significantly, between the teachers of the superior teaching, that what act in the basic cycle and in the vocational cycle. In this sense, it is possible to affirm that the reflexes of this integration happen so much in the secondary education how much in the teaching of engineering.

Finishing, we reiterate our thanks to the schools of Blumenau/SC that secured partnership in the project: EEB Hercílio Deeke, EEB Governor Celso Ramos, EEB. Valério Gomes and ETEVI - Technical School Cost of the Itajaí, to the FINEP – Financiadora of Studies and Projects, the financial support that enabled the execution of the project ENERBIO, and to the Regional Management of Education at Department of Education of the State of Santa Catarina (15th GERED), for mediating the dialogue with the High Schools of Blumenau.

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Time-Speed-Distance Foot Rally as a Tool for Campus Presentation

Marcelo Marques Gomes, Roberto Scalco, Daniela Caio André Gomes, Jorge Kawamura

Ciclo Básico, Centro Universitário do Instituto Mauá de Tecnologia, São Caetano do Sul, SP, Brazil

Email: marcelo.gomes@maua.br, roberto.scalco@maua.br, daniela.caio@maua.br, jorge.kawamura@maua.br

Abstract

Since 2002, the Engineering course of the Escola de Engenharia Mauá greets freshmen during their first week of classes with different activities aiming to present activities related to Engineering course, to promote integration among the freshmen and to present the Campus. One of the activities consisted of a self guided tour, which showed the facilities and departments for the freshmen. It was proposed in 2009 the activity "Trekking de Regularidade", also known as Time-Speed-Distance (TSD) Foot Rally, to replace a guided tour, so that the students could perform an activity that was able to recognize the campus, to promote integration and also introducing them to a sport that promotes teamwork and contact with nature.

Keywords: Time-Speed-Distance Foot Rally, Campus presentation, Freshmen.

1 Introduction

In 2001, it was proposed some different activities to first grade of the Engineering students at Escola de Engenharia Mauá (EEM). This project, called "Projeto Primeira Semana", was composed of speeches, evaluated activities assigned to students and a guided tour of the Campus of São Caetano do Sul. "Projeto Primeira Semana" aims to introduce simple engineering problems to freshmen, stimulate analytical solution of Mathematics and Physics with previously acquired knowledge, present the Campus and promote integration among freshmen (Marim, et al., 2013).

1.1 Previous activities

Between 2002 and 2007, the presentation of Campus to freshmen was guided by a professor. This visit was intended to present dependencies, sectors and services offered to students throughout their academic life. The different visited sectors introduce its main activities, restrictions, hours of operation and so on.

In 2008, the activity "Área Construída do Campus" replaced the guided tour. This activity requested that each team, composed of four students, visited one building of the Campus and estimated its dimensions for subsequent building area's calculation. On returning to the classroom, the professor managed the information obtained by the teams to determine the total area visited. However, it was realized that these students did not have a Campus overview.

In 2009, inspired by the experience gathered throughout two years of participation in competitions of Time-Speed-Distance Foot Rally competition, some professors, Scalco, Gomes, Gomes, & Kawamura (2010) proposed the activity "Trekking de Regularidade", which has for objectives the presentation of the Campus, sectors and their services (retaken after the gap in 2008); integration of new students; deadlines and practice of a physical activity.

2 Time-Speed-Distance Foot Rally

There is a misunderstood between the words "trekking" and "hiking" in Brazil. In fact, it is used the word "trekking" in the meaning of "hiking". According to dictionary:

- hiking (2013) is a walk for a long distance, especially across country;
- trekking (2013) is a long arduous journey, especially one made on foot.

Of course, this activity does not represent an arduous journey, so the correct term should be hiking, instead of trekking. Anyway, here in Brazil the term trekking is widely used to define the sport. Beyond this point of this work, the words hiking and trekking may have the same meaning, and should be interpreted in the context for this paper.

According to Mendonça (2005), the etymology of the word trekking considers the word trekken is originated from long trips and expeditions of the English settlers in South Africa, in the 1850s.

It is important to note that hiking is not a running, so the physical conditioning is not the main factor for this activity. Furthermore, this practice can be divided into three categories:

- a) **trekking:** a hiking that lasts several days;
- b) **speed trekking:** the winning team is the one that fulfill all the tasks in the shortest possible time;
- c) **Time-Speed-Distance Foot Rally:** the winning team is the one that fulfill all the tasks closest to the given time (ideal time).

In this activity, each team must calculate the ideal times to be met along the way. The distances need be estimated without precision instruments. For execution of this activity it is needed a roadmap with instructions using tulip arrows notation (DeWolfe, 2001), a calculator, a pencil, a watch and a compass.

2.1 A few definitions

In this section will be presented the main terms of the Time-Speed-Distance Foot Rally.

Roadmap

The roadmap shows the path that the team must follow. It has relevant information about distances that must be traveled and the indications of the directions and velocities to be observed. The figure 1 shows an example. References are given using tulip arrows notation (DeWolfe, 2001).

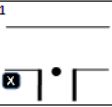

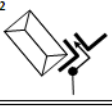
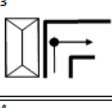
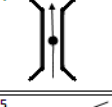



Distance	Reference	Comments
Section 01		Speed: 55 m/min
000 000		 Heading NORTH
33 33		
17 50		Take 2 minutes to read information
... ...		Cross the bridge
21 71		 Direction 290°
117 188		First trail to the right

Figure 1: Example of a roadmap

Each row of the roadmap represents a point which the team must pass through. These points are called references and they are numbered sequentially from the beginning of the roadmap (Jaguar Clubs of North America, Inc., 2013).

First column has two numbers: the upper one represents the distance, in meters, from one reference to another, and the lower one represents the accumulated distance from the beginning of the section to the actual reference.

In the second column there is a graphical representation of the place where the team must pass through: the pictures show how the team must navigate between streets or buildings in each reference, using tulip notation. There is a number at the top left showing the number of the reference.

The third column represents the comments of the section and express information to help the team in the choice of direction to proceed.

Checkpoints and Penalties

Along the path are positioned checkpoints (CPs) (Northbrasil, 2010), where the current time is noted by each team. It is assigned a penalty for the team in each CP, proportional to the difference in seconds between the current time and the ideal passage time, described in Table 1.

Table 1: Penalties on each CP

Situation	Penalty
Arriving late at CP	1 point per second
Arriving early at CP	2 points per second
Arriving more than 10 minutes late at CP	600 points
Arriving more than 5 minutes early at CP	600 points
Miss CP	600 points by missed CP

In addition to the penalties described in Table 1, each team may be penalized if their elements are too distant from each other, at 600 points per incident. This rule prevents teams to use "scouts", which are students that walk the path ahead of the team, warning of the presence of CPs.

The winner team is the one that lose the smallest number of points during a match. The evaluation of each team will be depending on its placement in the ranking of the class.

Distance estimates

For making navigation between references, teams must check the distance indicated on the roadmap and walk for that distance.

In a competition of this nature, one of the team members is responsible for the estimate the traveled distance. This can be done by counting footsteps.

Gomes & Parteli (2001) show that it is possible to establish a relation between the size of the footstep and the height of a person.

The student responsible for step counting must add one unit to the count when the same foot touches the ground. Illustration in figure 2 shows a step cycle. When the right foot touches the ground is added one to step count.



Figure 2: Cycle of one step

Calculation of ideal times

From the distance and speed of each section, it is possible to determine the instant when the team must pass in each reference. To control speed, the team must verify the clock and check if it is early or late when they pass on each reference.

The ideal times for each reference should be calculated in the sexagesimal system, whose base is the number 60. To express this value, we use the notation **hh:mm:ss**.

Division of tasks

As in any team sport, the affinity is a critical point that good results be achieved. The figure 3 shows which information is required during activity.

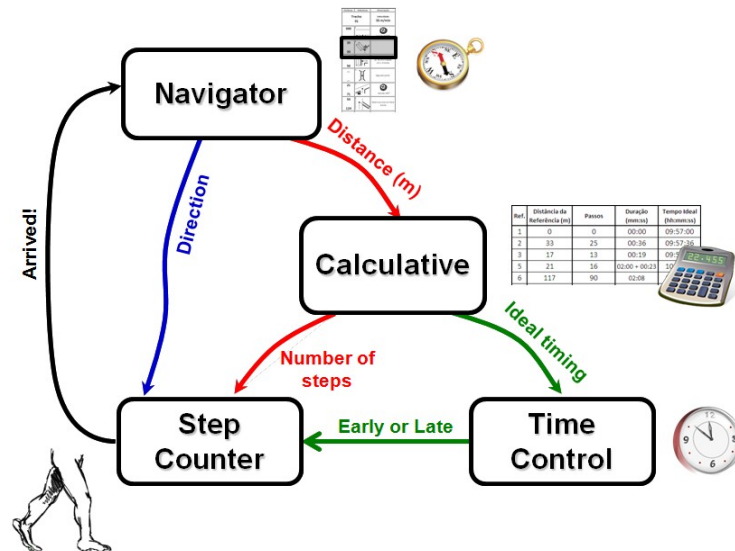


Figure 3: Information flow

3 Development and Application of Activity

The Instituto Mauá de Tecnologia (IMT) has a Campus in São Caetano do Sul with 21 buildings, as well as the Sports and Physical Activities Center - CEAF with covered gymnasium with three courts, soccer field, running track and pool, plus living area, parking lots and so on, counting a total area of 129,352 m² (Instituto Mauá de Tecnologia, 2005), more than enough space for the development of the activity.



Figure 4: Aerial view of the Campus

3.1 Routes Planning

At first, it was designed a path that included points of interest for the freshmen to know the various sectors of the Campus. Then, there were determined possible distances between references and the speeds in each section.

To avoid agglomeration among students along the way, it was decided that teams would start every 2 minutes. In addition, four other routes were prepared by Campus, separated by roadmaps with different colors. The activity was held in three days, during morning and evening classes.

Each of these five routes were drafted to include approximately 2.0 km and take about 55 minutes, with an average speed of approximately 36 meters per minute, speed considered low for such activity. For this distance, it was decided

that would be allocated 6 CPs along each route. From the distances and selected references were prepared roadmaps with Tulip notation.

From Sectors of interest located in Campus were created Information Stations (ISs), in contrast to CPs, these do not have the task of scoring, but only to inform to the students about activities in each sector. Each route must contain five of these ISs and the students who circulate through these routes should record one of the activities developed in those sectors. The nine ISs created were: Library, Technical Services and Tests Center, Sports and Physical Activities Center, Service to Students, Industrial Automation Laboratory, Electrical Engineering Laboratories, Computational Methods Center, Pilot Plant and the Dean's Office.

3.2 Training of the Teaching Staff

By the amount of students, the realization of the activity was divided into 17 classrooms (10 in the morning and 7 in the evening) with 80 students each. Thus, it became necessary to invite 15 professors for the application of this activity, since, throughout the project, the activities are given by pairs of professors in each classroom.

So that the activity would be conducted evenly, and for the lack of experience of professors in the sport, it has been proposed training sessions for professors.

During training sessions, professors acted as the students themselves, that is, attended a presentation in Microsoft PowerPoint about the sport, use of compass, reading roadmap, navigation, estimation of distances, calculation of ideal times and division of tasks among students of each team.

Then professors received roadmaps and made the calculations of the ideal times and the number of footsteps of each section.



Figure 5: Training offered to professors

So that professors could help students during the conduct of the activity, it was essential that they traveled the route, by noting times on each CP and the information of the ISs. With this, there was a friendly match among professors!

3.3 Calculation of Results

During the interval of thirty minutes between the arrival of the first and last teams, the professor divided the blackboard into nine regions corresponding to each ISs. The professor guided the teams on arrival to note in their region blackboard the information obtained in each IS.

Students were instructed to return to the classroom when completing the route and inform the professor their times on each PC. These information were inputted on a Microsoft Excel worksheet.

After the arrival of the last team, the blackboard became a panel summarizing the main activities and services of the various sectors of the Campus.

Finished typing the times of teams on each CPs, the sum of penalties along the track, as the ranking of the teams, are shown.

3.4 Evaluation and Award

The spreadsheet of verification is also responsible for generating the grade of every team. The team with the lowest score on the sum of missed points besides winning, had assigned the maximum grade. To emphasize the activity's sporting aspect the winners' teams in each classroom are awarded with customized medals. The other teams are assigned grades that vary according to the position on the rank of that group.

In case of adverse weather, there is an option to delay the start time in 30 minutes. However, if after 30 minutes weather condition did not improve, a presentation was made to freshmen with pictures of the main points that would be seen along the track as well as the services available to students at the Sports Center. In this case, evaluation was made based on the calculation of six ideal times chosen according to the route.



Figure 6: Awarded team

In case of adverse weather, there is an option to delay the start time in 30 minutes. However, if after 30 minutes weather condition did not improve, a presentation was made to freshmen with pictures of the main points that would be seen along the track as well as the services available to students at the Sports Center. In this case, evaluation was made based on the calculation of six ideal times chosen according to the route.

4 Results

The activity was done with 5.645 students, since 2009 up to 2013. Table 2 shows the participation teams number in this period, as morning classes as evening classes.

Table 2: Total number of teams

Year	Morning course	Evening course	Total
2009	180	123	303
2010	191	112	303
2011	163	103	266
2012	164	105	269
2013	178	116	264
			1435

In the subsequent week to the “Projeto Primeira Semana”, the students answered a survey, this asked how their opinion about activities. Between 2010 and 2011, 1728 students answered the survey. Two question were more important:

Question 1: Considering “Trekking de Regularidade” the activities' aims were:

1. Presentation of Campus
2. Presentation of sectors and their services
3. Integration among team members
4. Meet deadlines
5. Physical activity

Alternatives:

- ★ ★ ★ ★ ★ The objectives of the activity were fully achieved
- ★ ★ ★ ★ Almost all the objectives of the activity were achieved
- ★ ★ ★ The objectives of the activity were moderately achieved
- ★ ★ The objectives of the activity were practically not achieved
- +

For this question, 72.1% reported that all or most of aims were achieved during the activity. The graphic below (figure 7) show the distribution of answers.

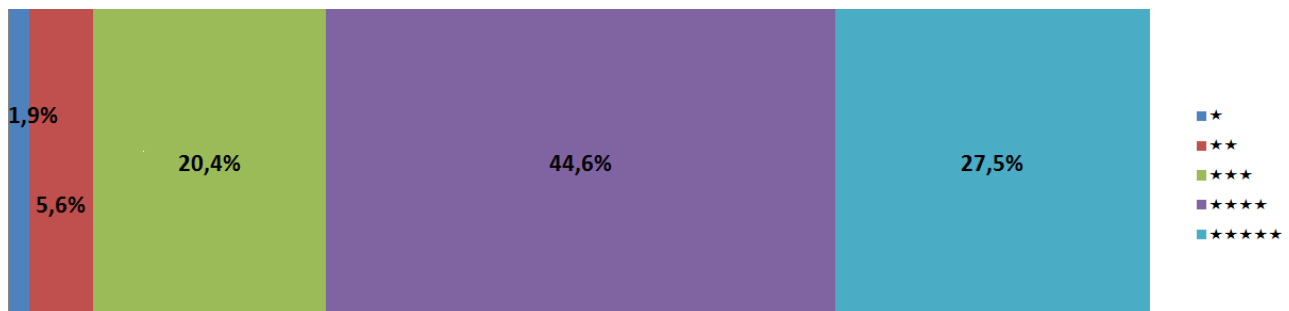


Figure 7: Objectives

Moreover, it was asked how was the integration among the team members, even subjectively.

Question 2: How do you consider the participation of team members during the activity "Trekking de Regularidade"?

Alternatives:

- ★ ★ ★ ★ ★ There was integration among all team's member
- ★ ★ ★ ★ The most team's member were engaged to execute their tasks
- ★ ★ ★ Some team's members were engaged to execute their tasks
- ★ ★ My team had difficulties in the task's division
- +

The first attempt got 69.5% of answers, while the second was marked by 19.1%, as show in figure 8. This show that the most of freshmen realized that teamwork was essential for the good performance of the activity.

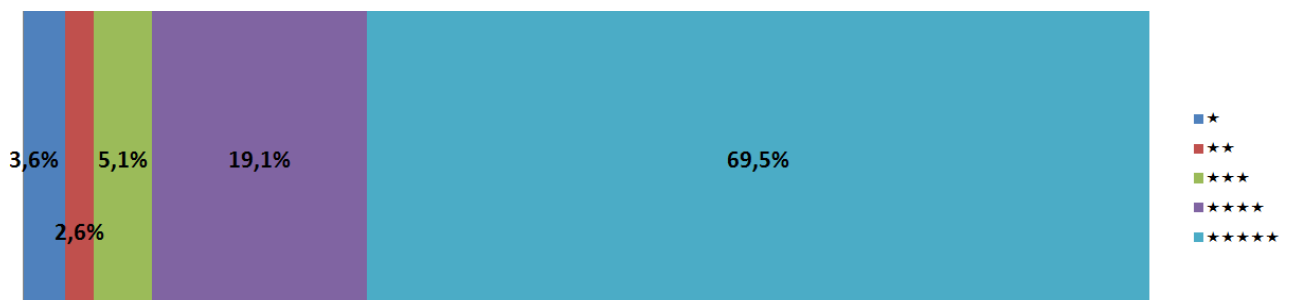


Figure 8: Integration

The analysis of these results shows that freshmen were engaged and motivated to accomplish the activity.

5 Final Considerations

Throughout five years when this activity was applied, the rallymasters could notice that most of the teams manage to navigate without problems. However, some other teams needed to be helped on several occasions. Teams with the most difficulties were addressed more frequently by rallymasters.

In some cases, rescue was required for completely disoriented teams, so they were instructed to return to the classroom.

With respect to the route, only one routes point had a special attention during the evening due to poor lighting. At that point, were designated rallymasters equipped with flashlights.

The experiment has shown to be valid from the point of view of attaining the proposed objectives. However, the organizers expected greater interest for the sport among the students.

It was noticed the commitment of applicators professors, who were interested in the activity and the sport. The format of the applied training to those professors proved to be correct and essential for the proper conduct of the activity, because it allowed to the professors to work around situations that are not trivial.

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